Section I—Air and Fallout

GROSS BETA ACTIVITY IN AIRBORNE PARTICULATES AND PRECIPITATION

Continuous surveillance of gross beta activity in air and precipitation provides one of the earliest and most sensitive indications of changes in environmental fission product activity. Although this surveillance does not provide enough information to assess total human radiation exposure from fallout, it is used as an alerting system for determining when to intensify monitoring in other phases of the environment.

Surveillance data from a number of national programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

1. Radiation Surveillance Network April 1965

Division of Radiological Health
Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Surveillance Network (RSN) of the PHS Division of Radiological Health, which regularly gathers samples from 75 stations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

Alerting function

The alerting function of the network is provided by field estimates of the gross beta activity of airborne particulates on the filters. These determinations are performed about five hours after the end of the sampling period to allow for decay of the naturally occurring radon daughters. The daily field readings are submitted to the Radiation Surveillance Center, Division of Radiological Health, Washington, D.C. These field estimates are reported elsewhere on a monthly basis (*1*). When unusually high air levels are observed, appropriate Federal and State officials are promptly notified.

Air sampling procedure and results

Airborne particulates are collected continuously on carbon-loaded cellulose dust filters four inches in diameter. About 1800 cubic meters of air are drawn through each filter during the 24-hour sampling period by a high volume centrifugal blower.

The filters are forwarded to the Radiation Surveillance Network laboratory in Rockville, Maryland, where the gross beta activity is measured using a thin-window, gas-flow proportional counter, calibrated with a strontium–90-yttrium–90 standard. Each filter is counted 4 days after the end of the sampling period and again 7 days later if the net count rate is 2000 cpm or higher. The initial four-day aging of the sample eliminates interference from naturally occurring radon and thoron daughters. By using the two counts and the Way-Wigner formula (*2*), the age of fission products is estimated, and the activity extrapolated to the day

Figure 1. Radiation Surveillance Network sampling stations

of collection.[1] The April 1965 average gross beta concentrations in air for RSN stations are given in table 1. Time profiles of gross beta activity in air for eight RSN stations are shown in figure 2.

Radioactivity in precipitation

Continuous sampling for radioactivity in total precipitation is conducted at most stations on a daily basis, using funnels with collection areas of 0.4 square meter. A 500-ml portion of the collected precipitation is evaporated to dryness, and the residue is forwarded to the laboratory for analysis. If the collected sample is between 200 and 500 ml, the entire sample is evaporated. When a sample is smaller than 200 ml (equivalent to 0.5 mm or 0.02 inches of rainfall), the volume of precipitation is reported, but no analysis is made.

In the laboratory the gross beta activity in precipitation is determined by counting the evaporated sample by the same method used for analyzing the air filters, including the extrapolation to time of collection. Deposition for the sample is determined by:

$$D = \frac{CP}{1000}$$

where D is the deposition in nCi/m², C is the concentration in pCi/liter, and P is the depth of precipitation in mm. The individual values of deposition and depth of precipitation are totaled for the month. Total depths of precipitation and deposition of radioactivity during April 1965 are presented in table 1.

Discussion

During April 1965, 20 air samples and 2 precipitation samples were analyzed by gamma spectrometry. The method discussed by Burrus (*3*) and Covell (*4*) was adapted for resolving the gamma scan data. As a matter of policy these samples are not generally destructively analyzed. Nineteen of the air samples and both precipitation samples contained long-lived nuclides such as ^{7}Be, ^{54}Mn, ^{137}Cs, $^{106}RuRh$, $^{144}CePr$, ^{65}Zn, and ^{125}Sb in small quantities. In

[1] If a sample contains a mixture of fresh and old fission products, the age estimated by the Way-Wigner formula is some intermediate value; consequently the calculated age of the fresh component will be overestimated.

Table 1. Gross beta activity in surface air and precipitation, April 1965

Station location		Air surveillance					Precipitation measurements	
		Number of samples	Gross beta activity, pCi/m³			Last profile in *RHD*	Total depth (mm)	Total deposition (nCi/m²)
			Maximum	Minimum	Average [a]			
Ala:	Montgomery	30	0.66	<0.10	0.29	May 65	27.1	5.5
Alaska:	Adak	27	0.49	<0.10	<0.17	Nov 64	[b]	[b]
	Anchorage	30	0.43	<0.10	<0.18	May 65	1.7	0.3
	Attu Island	25	0.27	<0.10	<0.15	Dec 64		
	Fairbanks	25	0.41	<0.10	<0.16	Jun 65	7.0	1.6
	Juneau	10	0.51	<0.10	<0.25	Sep 64	36.0	27.6
	Kodiak	17	0.64	<0.10	<0.19	Aug 65		
	Nome	15	0.20	<0.10	<0.12	Feb 65		
	Point Barrow	30	0.28	<0.10	<0.12	Jan 65		
	St. Paul Island	25	0.31	<0.10	<0.15	Mar 65		
Ariz:	Phoenix	28	1.08	0.15	0.44	Sep 64		
Ark:	Little Rock	26	0.62	<0.10	0.28	Jun 65	19.9	4.0
Calif:	Berkeley	24	0.45	<0.10	<0.15	Aug 65	92.7	18.6
	Los Angeles	30	0.44	<0.10	0.23	Feb 65	190.0	38.1
C. Z:	Ancon	11	0.27	<0.10	<0.13	Aug 65		
Colo:	Denver	29	1.11	<0.10	0.36	Aug 65	28.9	8.3
Conn:	Hartford	30	0.49	<0.10	<0.23	Oct 64	64.5	16.0
Del:	Dover	19	0.61	<0.10	0.26	May 65		
D. C:	Washington	28	0.61	<0.10	0.28	Feb 65	34.7	8.2
Fla:	Jacksonville	30	0.54	<0.10	0.27	Jun 65	51.6	11.9
	Miami	21	0.83	0.17	0.45	Oct 64	34.5	7.0
Ga:	Atlanta	2	0.13	<0.10	<0.11	Apr 65		
Guam:	Agana	29	0.88	<0.10	0.32	Apr 65		
Hawaii:	Honolulu	30	0.41	<0.10	<0.16	Dec 64	81.9	16.5
Idaho:	Boise	28	196.70	<0.10	7.30	Dec 64	66.2	13.3
Ill:	Springfield	29	0.69	<0.10	0.25	Feb 64		
Ind:	Indianapolis	27	0.45	<0.10	0.26	Apr 65	123.4	25.0
Iowa:	Iowa City	29	0.66	<0.10	0.27	Aug 65	184.6	37.4
Kans:	Topeka	25	0.39	<0.10	0.19	May 65	59.4	12.0
Ky:	Frankfort	26	0.66	<0.10	0.36	Feb 65	37.4	7.5
La:	New Orleans	30	0.46	<0.10	0.25	Feb 65	28.6	6.3
Maine:	Augusta	22	0.65	<0.10	0.28	Mar 65	80.6	16.1
	Presque Isle	29	0.47	<0.10	0.25	Aug 65		
Md:	Baltimore	21	0.48	<0.10	0.26	Oct 64	40.0	10.0
	Rockville	13	0.38	<0.10	0.22	Jan 65		
Mass:	Lawrence	30	0.52	<0.10	0.26	May 65	87.9	19.2
	Winchester	30	0.58	<0.10	0.31	Dec 64	77.1	16.0
Mich:	Lansing	30	0.65	<0.10	0.31	Jan 65	6.9	1.4
Minn:	Minneapolis	22	0.32	<0.10	<0.17	Apr 65	105.7	23.9
Miss:	Jackson	29	1.01	0.11	0.34	Dec 64	21.4	4.3
	Pascagoula					Dec 64		
Mo:	Jefferson City	29	0.61	<0.10	<0.22	Apr 65	100.6	20.3
Mont:	Helena	29	22.19	<0.10	1.19	Nov 64	22.8	26.50
Nebr:	Lincoln	20	2.43	<0.10	0.49	Mar 65	56.8	11.30
Nev:	Las Vegas	27	0.91	0.12	0.38	Jun 65	48.8	16.8
N. H:	Concord	21	0.64	<0.10	0.33	Feb 65		
N. J:	Trenton	30	0.60	<0.10	0.27	Mar 65	21.7	4.5
N. Mex:	Santa Fe	28	0.57	<0.10	0.27	Nov 64	16.3	3.6
N. Y:	Albany	22	0.55	<0.10	0.29	Apr 65	53.0	10.6
	Buffalo	27	0.79	<0.10	0.37	Aug 65		
	New York	25	0.49	<0.10	0.23	Dec 64		
N. C:	Gastonia	29	0.58	<0.10	0.29	Aug 65	117.3	23.5
N. Dak:	Bismarck	30	0.54	<0.10	<0.19	Jan 65	59.5	12.2
Ohio:	Cincinnati	17	0.45	<0.10	0.26	May 65		
	Columbus	28	0.80	0.11	0.45	Mar 65	166.0	34.7
	Painesville	30	0.72	<0.10	0.34	Oct 64	38.1	15.0
Okla:	Oklahoma City	30	0.71	<0.10	0.26	Jan 65	25.0	5.0
	Ponca City	27	0.41	<0.10	<0.16	Oct 64	61.1	12.8
Ore:	Portland	26	0.59	0.12	0.33	Mar 65	42.6	8.5
Pa:	Harrisburg	25	0.52	<0.10	<0.23	Apr 65	12.0	2.4
P. R:	San Juan	28	0.44	<0.10	0.20	Mar 65	82.9	16.5
R. I:	Providence	23	0.49	<0.10	<0.22	Jan 65	63.9	14.1
S. C:	Columbia	25	0.42	<0.10	0.22	Dec 64	70.7	14.2
S. Dak:	Pierre	27	0.52	<0.10	<0.20	Sep 64	14.1	6.7
Tenn:	Nashville	30	0.75	<0.10	0.32	Jan 65	119.8	27.0
Tex:	Austin	29	0.76	<0.10	0.25	May 65	46.2	9.3
	El Paso	27	1.11	0.20	0.54	Jan 65		
Utah:	Salt Lake City	27	0.64	<0.10	0.29	Feb 65	65.2	13.1
Vt:	Barre	26	0.70	<0.10	0.36	Jun 65	43.3	8.7
Va:	Richmond	30	0.56	<0.10	0.23	Jun 65	68.8	13.8
Wash:	Seattle	30	0.32	<0.10	<0.17	May 65	84.6	18.5
	Spokane	28	0.48	<0.10	0.26	Apr 65	24.8	7.0
W. Va:	Charleston	28	0.61	<0.10	0.31	Dec 64	161.1	32.3
Wis:	Madison	30	0.56	<0.10	0.26	Jun 65	91.1	27.6
Wyo:	Cheyenne	30	0.70	<0.10	0.34	Jun 65	10.8	3.5
Network summary [c]		1909	196.70	<0.10	<0.37		61.4	14.1

[a] The monthly average is calculated by weighting the individual samples with the length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If the <0.10 values represent more than 10 percent of the values used in the average, a less-than sign is placed before the average.
[b] Blank indicates no report received.
[c] For the network summary, all averages are arithmetic means of station averages.

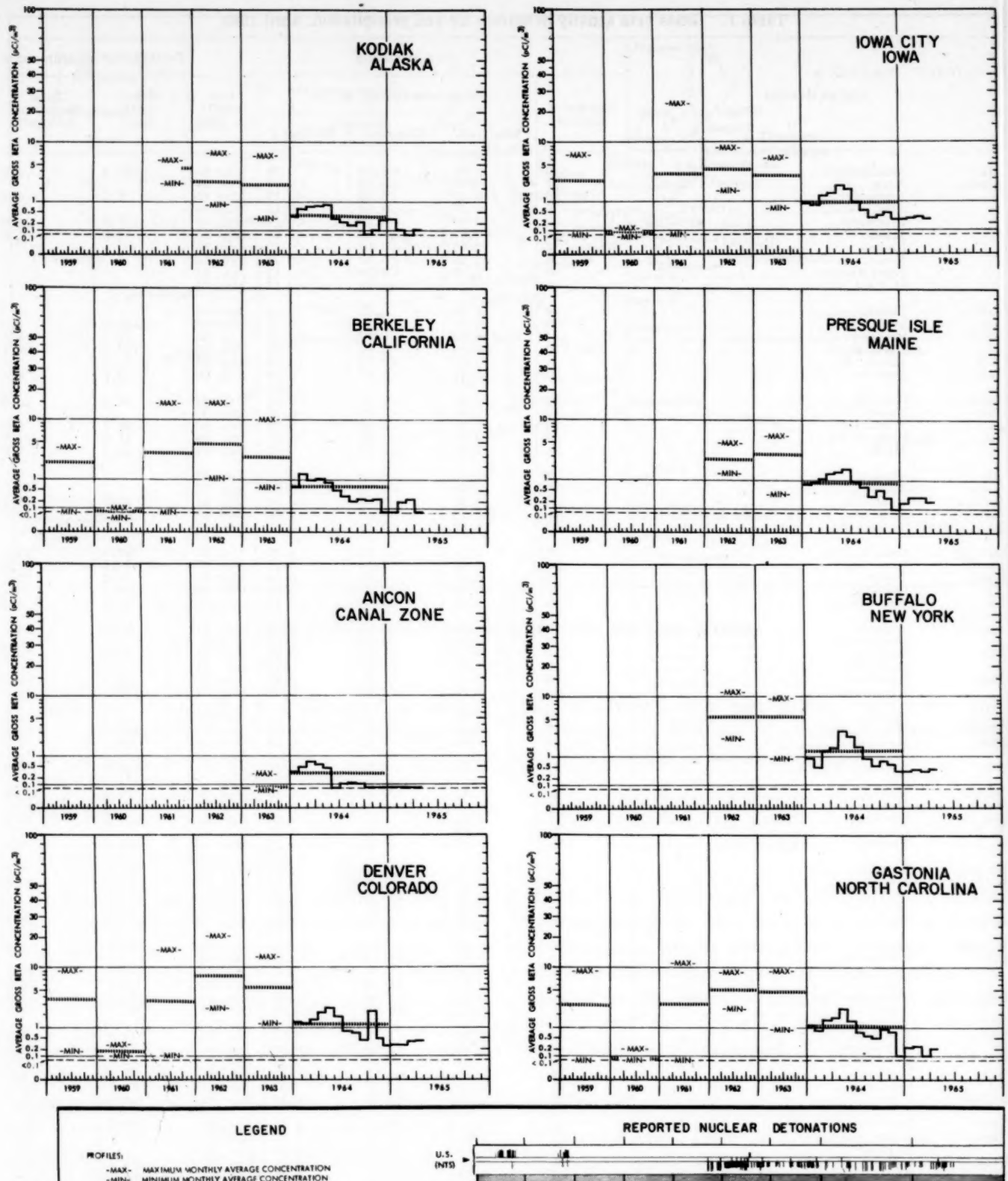

Figure 2. Monthly and yearly profiles of beta activity in air—Radiation Surveillance Network, 1959–April 1965

addition twelve air samples and both of the precipitation samples contained fresh fission products in identifiable quantities. Fresh fission products were identified in the daily samples from the network stations, as listed below:

Boise, Idaho	April 15, 16, and 17
Helena, Montana	April 16, 17, and 19
Cheyenne, Wyoming	April 16
Phoenix, Arizona	April 16
Denver, Colorado	April 16
Oklahoma City, Okla.	April 18
Lincoln, Nebraska	April 19
Jackson, Mississippi	April 22

Only two air samples were of sufficient activity to obtain an estimated age of the fresh fission products. These samples, collected on April 16 at Boise, Idaho, and Helena, Montana, exhibited observed ages of two days and one day, respectively.

The time relationship of the appearance of the fresh fission product material in these samples is consistent with the release of small quantities of radioactivity associated with the nuclear test conducted in Nevada on April 14, 1965, as reported in *Radiological Health Data*, page 289, May 1965.

2. Canadian Air Monitoring Program[2] April 1965

Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meterological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*5–9*).

Air sampling procedure and results

Each air sample involves the collection of particulates from about 650 cubic meters of air drawn through a high-efficiency 4-inch-diameter glass fiber filter during a 24-hour period. These filters are sent daily to the Radiation Protection Division Laboratory in Ottawa.

For analysis, a 2-inch-diameter disk is cut from each filter and counted with a thin-end-window, gas-flow, Geiger-Mueller counter system calibrated with a ^{90}Sr–^{90}Y standard. Four successive measurements are made on each filter to permit correction for natural activities

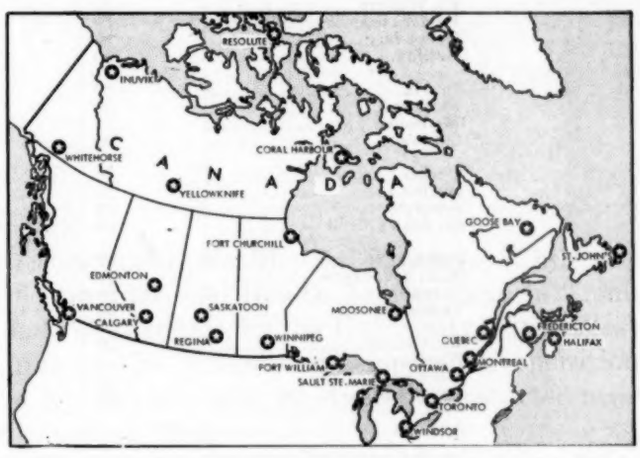

Figure 3. Canadian air and precipitation sampling stations

and for the decay of short-lived fission products. The results are extrapolated to the end of the sampling period. Canadian air data for April 1965 are given in table 2.

Precipitation collection and analysis

The amount of radioactive fallout deposited on the ground is determined from measurements on material collected in special polyethylene-lined rainfall pots. The collection period for each sample is one month. After transfer of the water to the sample container, the polyethylene liner is removed, packed with the sample, and sent to the laboratory.

Strontium and cesium carriers are added to all samples on arrival at the laboratory. Other carriers are added to selected samples according to the specific radionuclides to be determined. The samples are then filtered and the filtrate evaporated to near dryness. The filter

[2] This report was prepared from information and data in the May 1965 monthly report, "Data from Radiation Protection Programs," Canadian Department of National Health and Welfare, Ottawa, Canada.

paper containing insoluble matter is then ignited together with the polyethylene liner at 450°C. The ash is combined with the soluble fraction, transferred to a glass planchet, evaporated under an infra-red lamp, and then counted with a thin-end-window Geiger-Mueller counter calibrated with a strontium–90—yttrium–90 source. Gross beta activities for April 1965 samples are given in table 2. Radionuclide analyses are reported quarterly in *RHD*.

Table 2. Gross beta activity in surface air and precipitation, Canada, April 1965

Station location	Air surveillance				Precipitation measurements	
	Number of samples	Gross beta activity, pCi/m³			Average concentration, (pCi/liter)	Total deposition (nCi/m²)
		Maximum	Minimum	Average		
Calgary	30	0.7	0.1	0.3	301	3.7
Coral Harbour	29	0.5	0.1	0.3	141	1.7
Edmonton	30	0.3	0.1	0.2	264	4.3
Ft. Churchill	27	0.4	0.1	0.2	109	2.0
Ft. William	30	0.6	0.1	0.3	177	7.7
Fredericton	30	0.6	0.1	0.3	107	5.8
Goose Bay	30	0.5	0.1	0.3	139	5.9
Halifax	30	0.5	0.0	0.2	154	6.5
Inuvik	30	0.4	0.1	0.2	107	2.1
Montreal	30	0.7	0.0	0.4	95	6.0
Moosonee	30	0.5	0.1	0.3	292	4.4
Ottawa	30	0.5	0.0	0.3	119	7.7
Quebec	30	0.5	0.1	0.3	157	7.7
Regina	30	0.5	0.0	0.3	260	4.4
Resolute	29	0.5	0.2	0.3	108	0.8
St. John's, Nfld	29	0.5	0.0	0.2	98	10.0
Saskatoon	30	0.2	0.1	0.2	394	3.5
Sault Ste. Marie	29	0.8	0.0	0.4	241	10.2
Toronto	29	0.6	0.1	0.3	197	10.8
Vancouver	30	0.4	0.1	0.2	211	10.9
Whitehorse	30	0.5	0.0	0.2	321	1.6
Windsor	30	0.6	0.0	0.3	245	11.9
Winnipeg	30	0.6	0.0	0.2	136	8.8
Yellowknife	30	0.5	0.1	0.2	108	1.5
Average		0.5	0.1	0.3	187	5.8

3. Mexican Air Monitoring Program April 1965

National Commission of Nuclear Energy

The Radiation Surveillance Network of Mexico was established by the Comisión Nacional de Energía Nuclear (CNEN), Mexico City. From 1952 to 1961 the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN (*10–14*).

In 1961 the CNEN appointed its Division of Radiological Protection to establish a new radiation surveillance network. This consists of 17 stations (figure 4), 12 of which are located at airports and operated by airline personnel. The remaining 5 stations are located at Mexico City, Mérida, Veracruz, San Luis Potosí, and Ensenada. Staff members of the DRP operate the station at Mexico while the other four stations are manned by members of the Centro de Prevision del Golfo de Mexico, the Chemistry Department of the University of Merida, the Institute de Zonas Deserticas of the University of Baja, California, respectively.

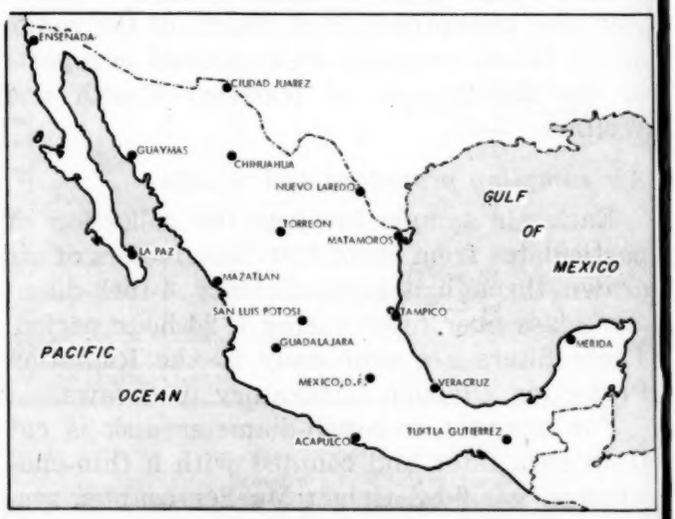

Figure 4. Fallout network sampling stations in Mexico

Sampling

The sampling procedure involves drawing air for 24 hours a day, 3 or 4 days a week at the rate of approximately 1200 cubic meters per day, through a high-efficiency, 6 x 8-inch glass fiber filter, using high volume samplers. After each 24-hour sampling period, the filter is removed and forwarded via airmail to the "Laboratorio de Estudios sobre Contaminación Radiactiva," CNEN, in Mexico City for assay of gross beta activity. A minimum of 3 days after collection is allowed for decay of radon and thoron daughter natural radioactivity. Data are not extrapolated back to the date of collection.

Results

The maximum, minimum, and average fission product beta concentrations in surface air during April 1965 are presented in table 3.

Table 3. Gross beta activity of airborne particulates, April 1965

Station	Number of samples	Gross beta activity (pCi/m³)		
		Maximum	Minimum	Average
Acapulco	6	0.1	<0.1	0.1
Ciudad Juárez	11	0.4	0.1	0.2
Chihuahua	10	0.6	0.1	0.2
Ensenada	12	0.3	0.1	0.2
Guadalajara	12		0.1	0.1
Guaymas	22	0.5	0.1	0.2
La Paz	10	0.5	0.1	0.3
Matamoros	8	0.2	<0.1	0.1
Mazatlán	1			
Mérida	10	0.1	<0.1	0.1
México, D.F.	8	0.1	<0.1	0.2
Nuevo Laredo	7	0.3	0.1	0.2
San Luis Potosí	10	0.1	<0.1	<0.1
Tampico	19	0.4	0.1	0.2
Torréon	17	0.3	<0.1	0.1
Tuxtla Gutiérrez				
Veracruz				

• Blanks indicate stations temporarily shut down.

4. Pan American Air Sampling Program April 1965

Pan American Health Organization and *Public Health Service*

Gross beta activity in air is monitored by four countries in the Americas under the auspices of a collaborative program, developed by the Pan American Health Organization and the Public Health Service (PHS), for assisting countries of the Americas in developing radiological health programs. The sampling equipment and analytical services are provided by the Division of Radiological Health, PHS, and are identical with those employed for the Radiation Surveillance Network.

The five air sampling stations included in the Program are operated by the technical staff of the Ministry of Health in each country. The station in Kingston, Jamaica, is operated by the Public General Hospital; in Caracas, Venezuela, by the Venezuelan Institute for Scientific Investigations; in Lima, Peru, by the Institute of Occupational Health; in Santiago, Chile, by the Occupational Health Service; and in Trinidad, West Indies, by the University of the West Indies. The Kingston station began operation in March 1964, and the others were started near the end of 1962.

The April 1965 air monitoring results from the four participating countries are given in table 4.

Table 4. Gross beta activity in air, April 1965 (Concentrations in pCi/m³)

Sampling stations	Number of samples	Maximum	Minimum	Average •
Kingston, Jamaica	19	0.53	<0.10	0.27
Caracas, Venezuela	18	0.12	<0.10	<0.10
Lima, Peru	17	0.10	<0.10	<0.10
Santiago, Chile	30	0.19	<0.10	<0.10
Trinidad, West Indies	20	0.16	<0.10	<0.10

• The monthly average is calculated by weighting the individual samples with length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If the <0.10 values represent more than 10 percent of the values used in the average, a less-than sign is placed in front of the average.

5. Gross beta activity in air, North America April 1965

From January 1963 through March 1965, monthly average concentrations of airborne gross beta activity in Canada and the United States were presented in combined form as isogram maps of most of North America. The data from the Radiation Surveillance Network and the Canadian Air Network were adjusted to each other by means of an intercalibration factor derived by Lockhart and Patterson (*15*).

With the formation of the Mexican Air monitoring program, new intercalibration ratios were determined, this time including the Canadian Network, Radiation Surveillance Network, Pan American Air Sampling Program, National Air Sampling Network, the HASL 80th Meridian Network, and the Mexican Network (*16*). The new intercalibration factors reflect some changes in standardization in both the RSN and the Canadian Air Network, effective September 1963.

In recent months, airborne gross beta activities have declined to such low levels that isogram comparisons are no longer meaningful. Before comparison with each other, the data from different networks must be multiplied by appropriate intercalibration factors. For example, if the Canadian data are considered as unity, the RSN and Pan American data must be multiplied by the intercalibration factor, 1.28, and the Mexican data must be multiplied by 0.81.

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AUTORADIOGRAPHIC EXAMINATION OF AIRBORNE FALLOUT FOR OCTOBER–NOVEMBER 1964

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Prior to and following the October 1964 detonation of a nuclear device on the Chinese mainland, autoradiographic techniques were used to study radioactive particulates in surface air at the Northeastern Radiological Health Laboratory in Winchester, Massachusetts. Both the number of radioactive particles and the gross beta activity per unit volume of air were investigated. This study was so designed because other ground level surveillance systems, operated by the Public Health Service during this period, included airborne radioactivity measurements but not determinations of the physical and radiological character of individual particles from weapons test debris.

This report presents both results of this study and comments on the usefulness of the autoradiographic approach as an indicator of the aerial intrusion of fresh fission products, especially where the overall increase in airborne gross beta activity is small.

Collection of particulates

Samples were collected using a positive displacement pump having a sampling rate of 1.3 cubic meters per minute[2] and fitted with an 8 x 10-inch (20.3 x 25.4-cm) filter holder. Collections were made on a membrane filter (pore size 0.8 micron). Selection of this filter was based on the fact that collected particles are deposited on the surface of the collecting medium. Sampling periods varied from one to three days. The total volume of air sampled ranged from 1000 to 4000 cubic meters per sample.

Method of film exposure

Several authors have described methods for autoradiographic examination of particles thus collected (*1–3*). The method consists of placing the filter on a holder, particles upward, in contact with "no-screen" x-ray film, and allowing exposure in darkness for a sufficient length of time to yield observable film darkening. When fresh fission product debris was indicated, the exposure time was standardized at seven days. The film holder was constructed so that the developed film could be realigned with the filter and the portions of the filter containing radioactive foci removed. The film was developed by standard techniques. Pressure was maintained over the film by insertion of several thicknesses of corrugated cardboard between the film and the top of the exposure chamber.

Counting the radioactive foci

Following development of the film, 2-mm diameter circles containing exposed areas, together with portions of the filter immediately below the film, were punched out. The filter disks were counted in a low-background anticoincidence beta counter. Areas of the filter which did not contain radioactive foci were counted to establish counter and filter beta activity "background." The diameter of the exposed spots was measured with a graticule and magnifier. The boundary of a focus was taken to be the periphery of absolute darkening and the beginning of the grayish area. Two arbitrary ranges of activity were established: (1) activities greater than 0.3 counts per minute, causing spot diameters between 0.25 and 0.5 millimeters, and (2) activities greater than 1 count per minute, causing spot diameters above 0.5 millimeters.

Concurrently with sampling for autoradiographic examination, the airborne gross beta activity was determined. Sampling apparatus

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[2] Sampling rate is measured at standard conditions of temperature and pressure.

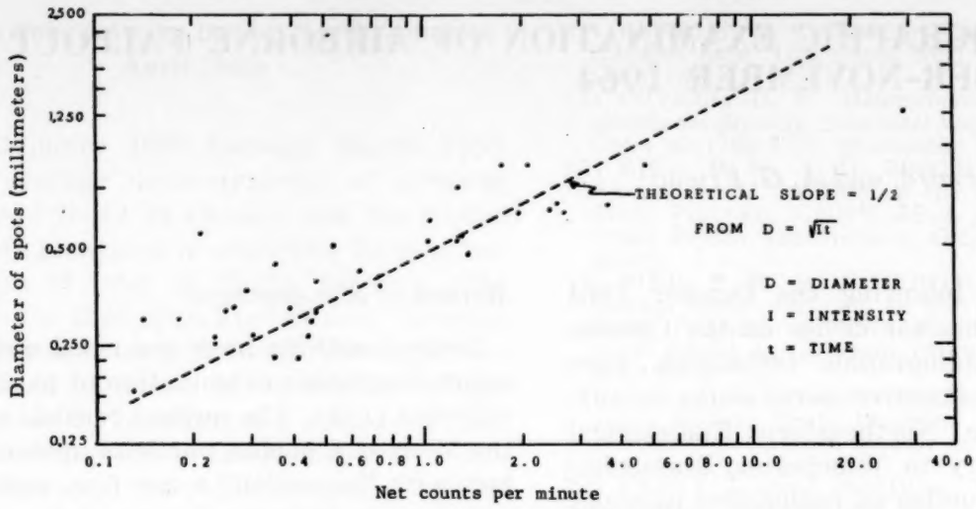

Figure 1. Diameter of autoradiographic spots *vs.* beta activity, sample for October 23-26, 1964

for this determination consisted of a self-lubricating vacuum sampling pump (sampling rate, 28–56 liters per minute), a flow meter and manometer, and a membrane filter holder (*4*). The sampler was capable of sampling 30 cubic meters of air in a 24-hour period through a 47-millimeter diameter membrane filter. Gross beta counting of air particulates was performed four days after the end of sampling to allow for radon and thoron daughter decay. Counting was done in a thin-window internal proportional counter, standardized with cesium–137.

To determine the number of radioactive foci relative to non-radioactive particles present, particles collected on a membrane filter were counted with an optical microscope at 100x, 430x, and 1000x (oil immersion). A 3200-square micron area of the filter was counted. This method is somewhat limited in that only particles above approximately 0.3 micron can be resolved.

Results and discussion

An air particulate sample collected prior to the intrusion of fresh fission products from October 16–19, 1964, showed no evidence of radioactive foci upon autoradiographic examination. During this period, gross beta activity of surface air particulates was 0.28 pCi/m³. For a sample collected from October 19–21, 1964, two radioactive foci were isolated (0.7 foci/1000m³); the gross beta activity for this period being 0.14 pCi/m³. A one-day sample collected on October 21, 1964, indicated the presence of 178 foci/1000m³ and a gross beta activity of 0.38 pCi/m³. This level of gross beta activity is within the limits of daily variations, but the presence of fresh fission products was confirmed by gamma spectral analysis. Thereafter, there was a rise in both the number of radioactive foci and the gross beta activity.

The air particulates sample collected from October 23–26, 1964, was used to relate spot diameter to beta activity and to check the validity of the beta counting and spot measuring techniques. The diameter, D, of the spot is theoretically related to activity and length of exposure by the equation $D = \sqrt{It}$, where I equals the intensity (activity) of the radiation, and t the length of exposure (*5*). Since t was held constant, D is proportional to $\sqrt{I}$.

The diameter of the spots plotted against the β activity on log-log paper was found to approximate the theoretically expected slope of 0.5 (figure 1). The correlation coefficient between activity and spot size was 0.55 and the 95 percent confidence interval for the correlation coefficient was $0.40 \leq r \leq 0.79$.

Figure 2 illustrates the variation in airborne gross beta activity, the number of radioactive foci present, and the relative distribution of activity per particle. The maximum air activity occurred during the collection period October 28–29, 1964 (2.38 pCi/m³), at which time the number of radioactive foci numbered 1365/1000m³. For the most part, increases in activity were accompanied by increases in the number of foci per unit volume of air. Several exceptions occurred, at which times lower numbers of radioactive foci were compensated for by a higher percentage of "hotter" particles.

During these periods, the percentage of foci with larger diameters increased, indicating an increased specific activity per particle. The most active particle isolated was from the sample collected October 23–26, 1964, and was estimated to contain about 30 pCi of beta activity. The radioactive particle concentrations determined during this study were within the range of 0.13 radioactive particles/m³ to 2.2 radioactive particles/m³, as reported by others (*6*, *7*).

In an earlier investigation of the particle size of airborne gamma emitting radionuclides, no relationship could be found between the amount of radioactivity collected in a particular size fraction and particle (radioactive and non-radioactive) diameter, weight, surface area, and number in the size fraction (*8*). It was theorized in that report that this was due to the relatively small number of radioactive particles compared to the number of non-radioactive particles. This is borne out by the data presented in table 1, which compare the number of radioactive foci (each focus is assumed to be due to a single radioactive particle) to the total number of particles present as determined by optical microscopic counting.

Table 1. Concentration of radioactive foci and total particles present in surface air, October 23–November 12, 1964

Radioactive foci/m³			Total number of particles/m³		Ratio: radioactive foci / total number of particles
Date	Number	Average number for period	Date	Number x 10^8	
10/23–26	0.42	0.42	10/23–26	1.11	3.8×10^{-9}
10/26–28 10/28–30	0.12 1.36	0.74	10/26–29	1.78	4.2×10^{-9}
10/30–11–1 11/1–3	0.51 0.12	0.31	11/1–4	1.82	1.7×10^{-9}
11/10–12	0.10	0.10	11/11–14	1.34	7.5×10^{-10}

Conclusions

It can be stated that the autoradiographic examination of airborne radioactive particles during an intrusion of fresh fallout indicated changes in the specific activity per particle and in the concentration of radioactive particles relative to gross beta activity. As a result of this study, the authors believe that autoradiographic techniques are a reliable method for substantiating the presence of fresh fallout from an atmospheric nuclear detonation, especially under conditions where the rise in airborne gross beta activity is small.

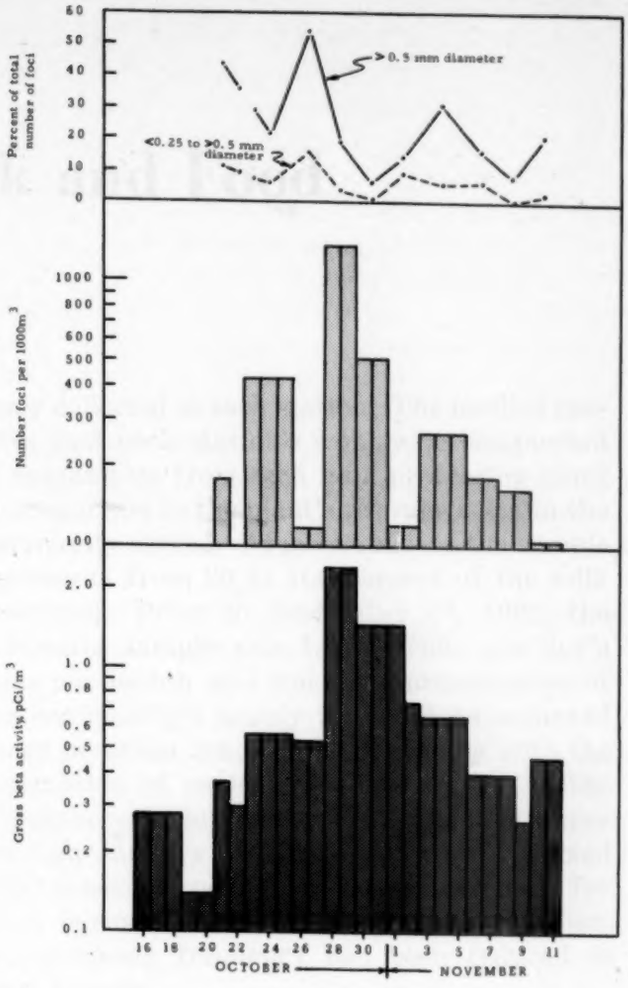

Figure 2. Results of autoradiography and gross beta activity from October 16 to November 12, 1964

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(*5*) Ibid., p. 28.

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Section II—Milk and Food

MILK SURVEILLANCE

Although milk is only one of the many sources of dietary intake of radionuclides, it is the single food item most often used as an indicator of the population's intake of radionuclides from the environment. This is because fresh milk is consumed by a large segment of the United States population and contains most of the radionuclides occurring in the environment which have been identified as biologically important. In addition, milk is produced and consumed on a regular basis, is convenient to composite and analyze, and samples which are representative of milk consumption in any area can be readily obtained.

1. Pasteurized Milk Network, April 1965

Division of Radiological Health, and
Division of Environmental Engineering and Food Protection, Public Health Service

The Public Health Service pasteurized milk surveillance program had its origin in a raw milk monitoring network (*1*) established by the Service in 1957. One of the primary objectives of this network was the development of methods for milk collection and radiochemical analysis suitable for larger scale programs.

Experience derived from this study led to the activation of a pasteurized milk sampling program with stations selected to provide nationwide surveillance of milk production and consumption areas. The present Pasteurized Milk Network (PMN), which consists of 63 stations, has at least one station in every State, the Canal Zone, and Puerto Rico.

Sampling procedure

Through the cooperation of State and local milk sanitation authorities, samples are routinely collected at each station. The method specifies that each station's sample be composited of subsamples from each milk processing plant in proportion to the plant's average sales in the community served. At most stations the sample represents from 80 to 100 percent of the milk processed. Prior to September 15, 1961, the composite sample was taken from one day's sales per month and was as representative of the community's supply as could be achieved under practical conditions. Beginning with the resumption of nuclear weapons testing in the atmosphere in September 1961, and continuing through January 1963, samples were collected twice a week at nearly all stations and daily for short periods at selected stations. Since then, the sampling frequency has been reduced to once a week.

Samples are preserved with formaldehyde and sent to the PHS Southwestern (SWRHL), Southeastern (SERHL), or Northeastern (NERHL) Radiological Health Laboratories for analysis. Gamma analyses for iodine–131 are made within 3 to 6 days after sample collection, and any results exceeding 100 pCi/liter are immediately telephoned to appropriate State health officials for possible public health action. Analytical results are normally available 6 to 7 weeks after weekly samples are received by the laboratories; publication in *RHD* follows 3 to 4 months after the monthly samples are composited for analysis.

Analytical procedures

Iodine–131, cesium–137, and barium–140 concentrations are determined by gamma scintillation spectrometry.[1] After the weekly samples are gamma scanned, samples from two consecu-

[1] Southeastern Radiological Health Laboratory employs a radiochemical procedure for barium–140 analysis.

tive weeks are composited and analyzed radiochemically for strontium–89 and strontium–90. There is an inherent statistical variation associated with all measurements of radionuclide concentrations. With the low radionuclide levels which are usually found in milk and other environmental samples, this variation on a percentage basis is relatively high. The variation depends upon such factors as the method of chemical analysis, the sample counting rate and counting time, interferences from other radionuclides, and the background count. For milk samples, counting times of 50 minutes for gamma spectrometry and 30 to 50 minutes for beta determinations are used. Table 1 shows the approximate total analytical error (including counting error) associated with radionuclide concentrations in milk. These errors were determined by comparing results of a large number of replicate analyses.

The minimum detectable concentration is defined as the measured concentration equal to the two-standard deviation analytical error. Accordingly, the minimum detectable concentrations in units of pCi/liter are: strontium–89, 5; strontium–90, 2; cesium–137, 10; barium–140, 10; and iodine–131, 10. At these levels and below, the counting error comprises nearly all of the analytical error.

Table 1. Analytical errors associated with estimated concentrations for selected radionuclides in milk

Nuclide	Estimated concentration (pCi/liter)	Error [a] (pCi/liter)	Estimated concentration (pCi/liter)	Error [a] (percent of concentration)
Iodine-131	0 to 100	±10	100 or greater	±10
Barium-140	0 to 100	±10	100 or greater	±10
Cesium-137	0 to 100	±10	100 or greater	±10
Strontium-89	0 to 50	±5	50 or greater	±10
Strontium-90	0 to 20	±2	20 or greater	±10

[a] Two standard deviations (σ).

Calcium analyses at SERHL are done by an ion exchange and permanganate titration method, while at NERHL and SWRHL an ethylenediaminetetraacetic acid (EDTA) method is used. Stable potassium concentrations are estimated from the potassium–40 concentrations[2] determined from the gamma spectrum.

[2] The conversion factor is 1.18 milligrams K/pCi^{40}K.

Data presentation

Table 2 presents summaries of the analyses for April 1965 (actual reporting period is March 28, 1965 to April 24, 1965). Barium–140 results are not presented because the monthly average concentrations in milk were less than 10 pCi/liter. Radionuclide values reported by a laboratory as being below the minimum detectable concentration have been averaged by using one-half the minimum detectable value. The averaging procedure was modified for iodine–131 and barium–140 in October 1963 when nondetectable concentrations of these radionuclides were considered zero. A similar procedure is used for the network average.

Figures 1 and 2 are isogram maps showing the estimated strontium–90 and cesium–137 concentrations in milk over the entire country. The value printed beside each station is the monthly average concentration for that station. The isograms were developed by arbitrary interpolation between values for the individual stations.

The distribution of monthly averages for strontium–90 and cesium–137 network stations for November 1964 through April 1965 are compared in tables 3 and 4. The average monthly strontium–90 concentrations in pasteurized milk from selected cities in the sampling program are presented in figure 3. Each graph shows the strontium–90 concentrations in milk from one city in U. S. Bureau of Census regions. This method of selection permits graphic presentation of data for each city in the network three times a year.

For special purposes of comparison and reference, the Network maximum, minimum, and average monthly radionuclide concentrations for the early years of operation (March 1960–March 1964) were summarized in tabular form in the July 1964 *RHD* (*2*). An annual summary for 1964 appeared in the April 1965 *RHD* (*3*).

Discussion of data

Neither iodine–131 nor barium–140 were found in PMN samples collected during the month of April 1965. Iodine–131 had last been detected in 45 milk samples during the period October 26 through November 30, 1964, and was attributed to the detonation of a nuclear device on the Chinese Mainland on October 16, 1964.

Table 2. Average concentrations of stable elements and radionuclides in pasteurized milk, April 1965 and the first quarter 1965 [a]

Sampling locations		Calcium (g/liter)		Strontium-89 (pCi/liter)		Strontium-90 (pCi/liter)		Cesium-137 (pCi/liter)	
		First quarter	April 1965	First quarter	April 1965	First quarter	April 1965	First quarter	April 1965
Ala:	Montgomery	1.19	1.18	<5	<5	19	23	55	60
Alaska:	Palmer	1.18	1.17	<5	<5	17	21	60	75
Ariz:	Phoenix	1.20	1.18	<5	<5	6	6	25	20
Ark:	Little Rock	1.18	1.16	<5	<5	34	38	70	75
Calif:	Sacramento	1.26	1.32	<5	<5	7	8	35	40
	San Francisco	1.27	1.23	<5	<5	8	12	35	45
C. Z:	Cristobal	1.14	1.13	<5	<5	5	4	40	40
Colo:	Denver	1.27	1.28	<5	<5	18	19	70	80
Conn:	Hartford	1.12	1.12	<5	<5	16	16	90	90
Del:	Wilmington	1.15	1.15	<5	<5	19	19	80	80
D. C:	Washington	1.17	1.18	<5	<5	17	16	60	60
Fla:	Tampa	1.18	1.16	<5	<5	13	12	160	170
Ga:	Atlanta	1.19	1.16	<5	<5	26	31	90	100
Hawaii:	Honolulu	1.18	1.21	<5	<5	11	12	65	60
Idaho:	Idaho Falls	1.21	1.26	<5	<5	21	20	110	100
Ill:	Chicago	1.12	1.12	<5	<5	17	16	90	95
Ind:	Indianapolis	1.19	1.18	<5	<5	17	18	75	65
Iowa:	Des Moines	1.20	1.26	<5	<5	22	23	60	70
Kans:	Wichita	1.24	1.26	<5	<5	18	20	55	55
Ky:	Louisville	1.17	1.15	<5	<5	22	24	60	55
La:	New Orleans	1.23	1.20	5	<5	43	47	80	100
Maine:	Portland	1.14	1.12	<5	<5	22	22	135	140
Md:	Baltimore	1.16	1.16	<5	<5	18	18	65	70
Mass:	Boston	1.16	1.15	<5	<5	23	22	140	150
Mich:	Detroit	1.15	1.14	<5	<5	16	17	85	90
	Grand Rapids	1.18	1.17	<5	<5	19	20	90	90
Minn:	Minneapolis	1.22	1.26	<5	<5	26	26	90	90
Miss:	Jackson	1.25	1.20	<5	<5	34	40	60	60
Mo:	Kansas City	1.22	1.20	<5	<5	22	23	60	55
	St. Louis	1.25	1.26	<5	<5	17	20	50	50
Mont:	Helena	1.25	1.29	<5	<5	18	22	95	115
Nebr:	Omaha	1.25	1.22	<5	<5	18	20	50	55
Nev:	Las Vegas	1.20	1.22	<5	<5	9	6	40	45
N. H:	Manchester	1.16	1.18	<5	<5	24	24	155	155
N. J:	Trenton	1.13	1.12	<5	<5	16	16	80	80
N. Mex:	Albuquerque	1.22	1.28	<5	<5	12	12	45	55
N. Y:	Buffalo	1.11	1.10	<5	<5	17	16	110	120
	New York	1.12	1.09	<5	<5	19	19	105	105
	Syracuse	1.11	1.09	<5	<5	16	17	95	100
N. C:	Charlotte	1.20	1.24	<5	<5	29	30	65	65
N. Dak:	Minot	1.21	1.24	<5	<5	52	61	125	120
Ohio:	Cincinnati	1.16	1.15	<5	<5	17	18	70	70
	Cleveland	1.16	1.16	<5	<5	18	20	95	100
Okla:	Oklahoma City	1.18	1.14	<5	<5	21	20	55	50
Ore:	Portland	1.28	1.29	<5	<5	20	24	100	95
Pa:	Philadelphia	1.16	1.14	<5	<5	17	18	80	80
	Pittsburgh	1.16	1.17	<5	<5	24	24	105	115
P. R:	San Juan	1.14	1.16	<5	<5	12	10	50	50
R. I:	Providence	1.16	1.14	<5	<5	19	16	100	110
S. C:	Charleston	1.20	1.20	<5	<5	30	30	85	100
S. Dak:	Rapid City	1.03	0.82	<5	<5	28	26	135	120
Tenn:	Chattanooga	1.22	1.16	<5	<5	31	30	70	70
	Memphis	1.20	1.14	<5	<5	26	26	45	45
Tex:	Austin	1.15	1.15	<5	<5	9	8	35	20
	Dallas	1.19	1.19	<5	<5	18	22	45	50
Utah:	Salt Lake City	1.30	1.35	<5	<5	25	24	125	130
Vt:	Burlington	1.12	1.11	<5	<5	21	20	120	120
Va:	Norfolk	1.19	1.20	<5	<5	21	21	60	60
Wash:	Seattle	1.26	1.24	<5	<5	23	21	90	90
	Spokane	1.28	1.30	<5	<5	26	29	100	105
W. Va:	Charleston	1.18	1.13	<5	<5	16	18	50	55
Wis:	Milwaukee	1.20	1.23	<5	<5	14	18	100	100
Wyo:	Laramie	1.25	1.24	<5	<5	13	18	65	75
Network average		1.19	1.18	<5	<5	19.9	20.9	79	82

[a] Results of iodine-131 and barium-140 analyses all below detectable levels.

Table 3. Frequency distribution, strontium-90 concentrations in milk at Pasteurized Milk Network stations, November–December 1964, January–April 1965, and April 1964

Strontium-90 (pCi/liter)	Number of stations						
	1964		1965				1964
	Nov	Dec	Jan	Feb	Mar	Apr	Apr
Under 10	6	8	6	3	5	5	4
10–19	31	29	32	31	29	23	12
20–29	19	20	19	22	21	27	28
30–39	6	4	4	5	6	5	12
40–49	1	2	1	2	1	2	2
50–59	0	0	1	0	1	0	2
60–69	0	0	0	0	0	1	3

Table 4. Frequency distribution, cesium-137 concentrations in milk at Pasteurized Milk Network stations, November–December 1964, January–April 1965, and April 1964

Cesium-137 (pCi/liter)	Number of stations						
	1964		1965				1964
	Nov	Dec	Jan	Feb	Mar	Apr	Apr
Under 50	15	9	11	8	9	7	2
50–99	41	38	38	38	36	35	12
100–149	4	14	12	15	16	18	23
150–199	2	2	2	2	2	3	17
200–249	1	0	0	0	0	0	7
250–299	0	0	0	0	0	0	2

Slight increases in the April strontium–90 monthly averages were observed for 30 stations while levels at 20 stations decreased slightly from the previous month. The network average strontium–90 concentration for April 1965 was 20.9 pCi/liter. This is only slightly above the March network average of 20.4 pCi/liter but is 23 percent lower than it was a year ago. The ratio of the highest concentration to the average concentration was 2.25 for April 1965 compared to 2.60 for March 1965.

The cesium–137 network average for 63 stations was 82 pCi/liter in April 1965 compared to 81 pCi/liter in March 1965. It is to be noted that the average for April 1965 was 41 percent lower than April 1964. The ratio of the highest concentration to the average concentration was 2.1 for April 1965 compared to 1.9 for April 1964. A continued decrease in radionuclide concentrations in milk should be observed, provided fresh fission debris is not introduced into the atmosphere.

A comparison of the 1965 results through April shows no evidence of the anticipated "spring rise" in strontium–90 or cesium–137 concentration in milk.

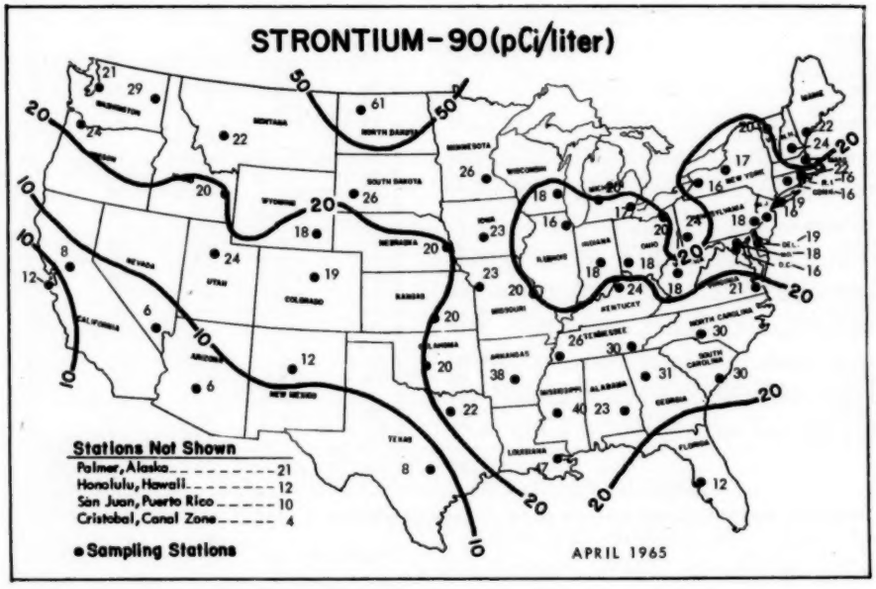

FIGURE 1.— STRONTIUM-90 CONCENTRATIONS IN PASTEURIZED MILK

Figure 1. Strontium–90 concentrations in pasteurized milk, April 1965

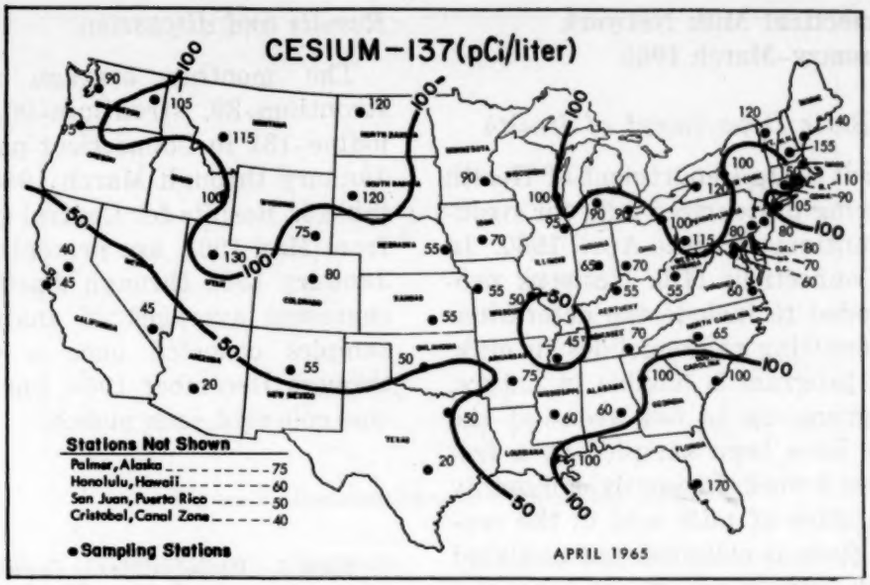

Figure 2. Cesium–137 concentrations in pasteurized milk, April 1965

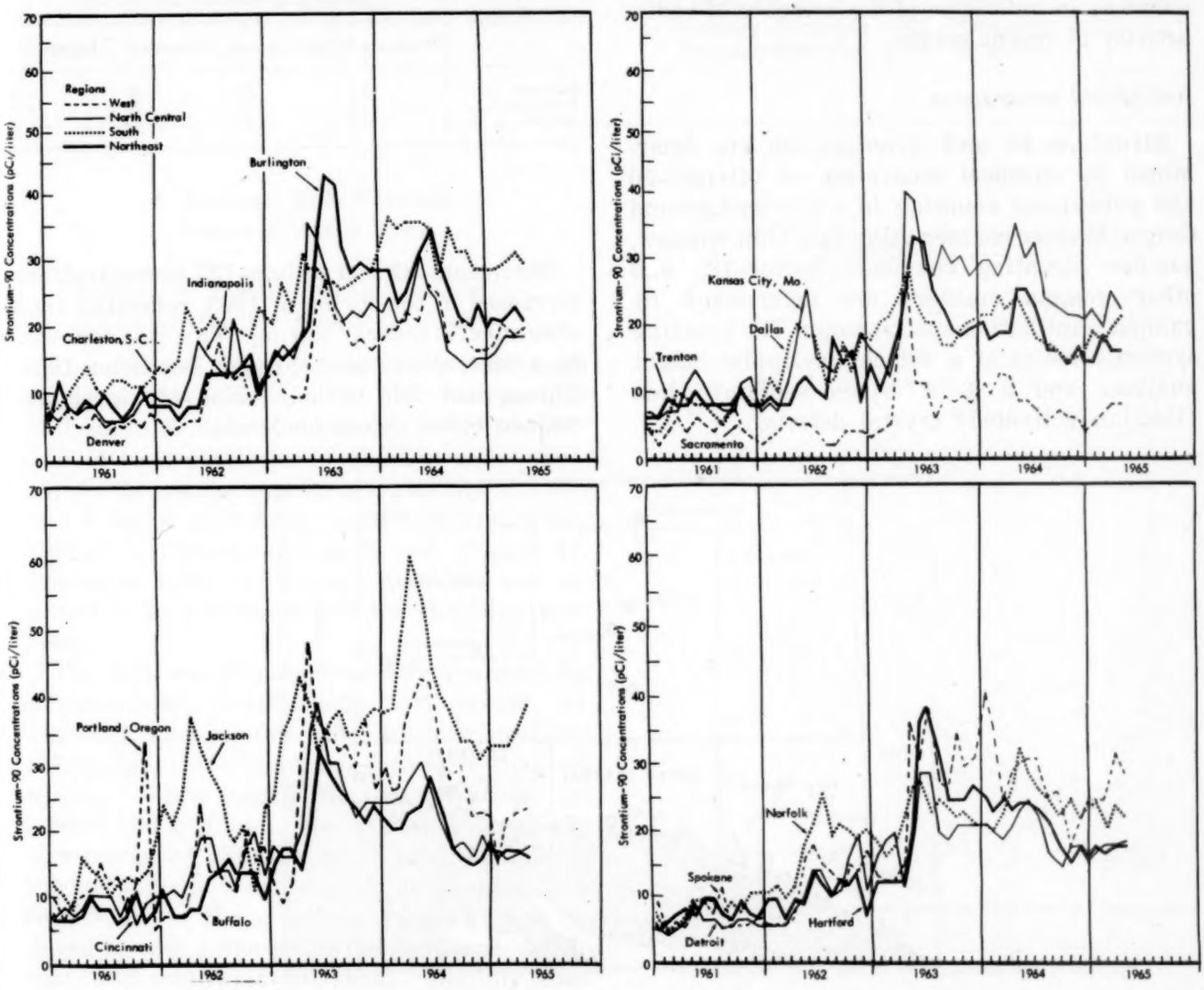

Figure 3. Strontium–90 in pasteurized milk, 1961—April 1965

2. Connecticut Milk Network January–March 1965

Connecticut State Department of Health

The Connecticut State Department of Health has been monitoring pasteurized milk for strontium–89 and strontium–90 since April 1960. In May 1962 the Connecticut Milk Network program was expanded to include the determination of gamma emitting radionuclides in milk.

The sampling program is flexible in nature. Under this program, up to five areas of the State (figure 4) have been sampled at a frequency up to twice a week. Presently, a monthly sample representative of milk sold in the central area of the State is collected and analyzed for strontium–89, strontium–90, and gamma emitters. Concentrations of iodine–131 are followed as an indication of the presence of radioactivity of recent origin.

Analytical procedures

Strontium–89 and strontium–90 are determined by chemical separation of yttrium–90 and subsequent counting in a low-background Geiger-Mueller counter utilizing a thin-window, gas-flow counting chamber. Iodine–131 and other gamma emitters are determined by gamma scintillation spectroscopy. The counting system consists of a 400-channel pulse height analyzer and a 4- x 4-inch sodium iodide (thallium-activated) crystal detector.

Results and discussion

The monthly average concentrations of strontium–89, strontium–90, cesium–137, and iodine–131 in Connecticut pasteurized milk for January through March 1965 are presented in table 5. Results for Central Connecticut, dating from May 1962, are presented in figure 5. For January 1963 through April 1964, the results represent averages of analyses of composite samples collected once a week; from May through December 1964, one composite sample was collected each month.

Table 5. Radionuclides in Central Connecticut milk, January–March 1965

Month	Radionuclide concentrations, pCi/liter			
	Strontium-89	Strontium-90	Cesium-137	Iodine-131
January	<1	13	80	<10
February	<1	15	70	<10
March	<1	15	30	<10

Strontium–89 and cesium–137 concentrations increased in the spring of 1963, reflecting 1962 atmospheric nuclear testing. This was followed by a decreasing trend through December 1964. Throughout this period, iodine–131 levels remained below detectable levels.

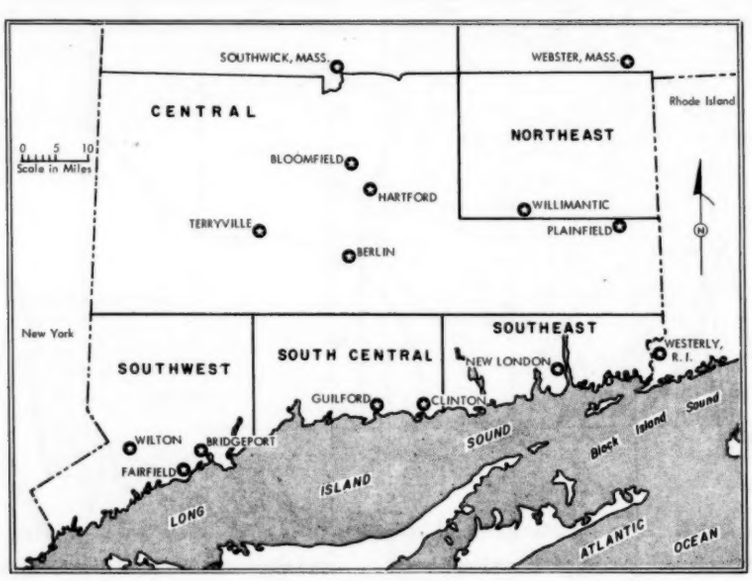

Figure 4. Connecticut milk sampling stations

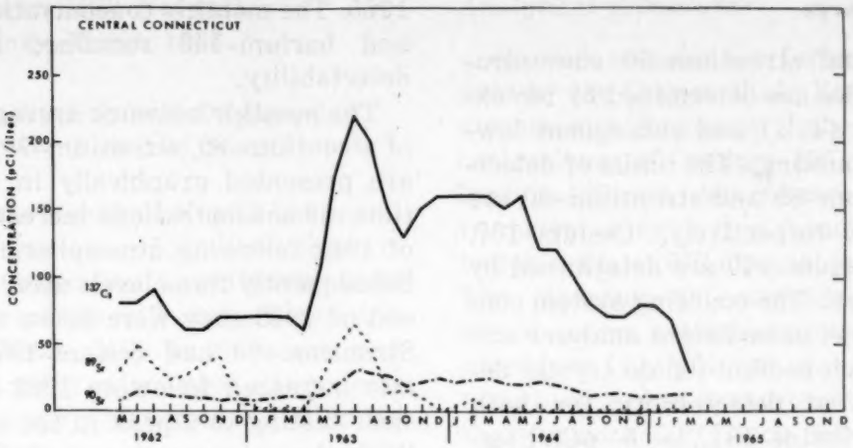

Figure 5. Radionuclides in Connecticut milk

During this period concentrations of strontium–89, strontium–90 and iodine–131 were below the levels for remedial action indicated by the recommendations of the Federal Radiation Council.

Recent coverage in *Radiological Health Data:*

Period	*Issue*
January–December 1963	*September 1964*
January–December 1964	*May 1965*

3. Indiana Milk Network January–March 1965

Bureau of Environmental Sanitation, Indiana State Board of Health

The Indiana State Board of Health began sampling pasteurized milk for radionuclide analysis in September 1961. To analyze radionuclide concentrations in Indiana milk effectively, the State was geographically divided into 5 major milksheds: northeast, northwest, central, southeast, and southwest (figure 6). One large dairy within each milkshed was assumed to be representative for sampling purposes.

The milk samples are routinely analyzed for strontium–89, strontium–90, cesium–137, iodine–131, and barium–140. Initially, cesium–137, iodine–131, and barium–140 were analyzed weekly. When iodine–131 concentrations exceeded 100 pCi/liter, the sampling frequency was increased. Since August 1963, because of the continued low concentrations of short-lived radionuclides, the sampling frequency was reduced to once a month for the northeast, southeast, and southwest milksheds. Monthly analyses for strontium–89 and strontium–90 are performed at each station.

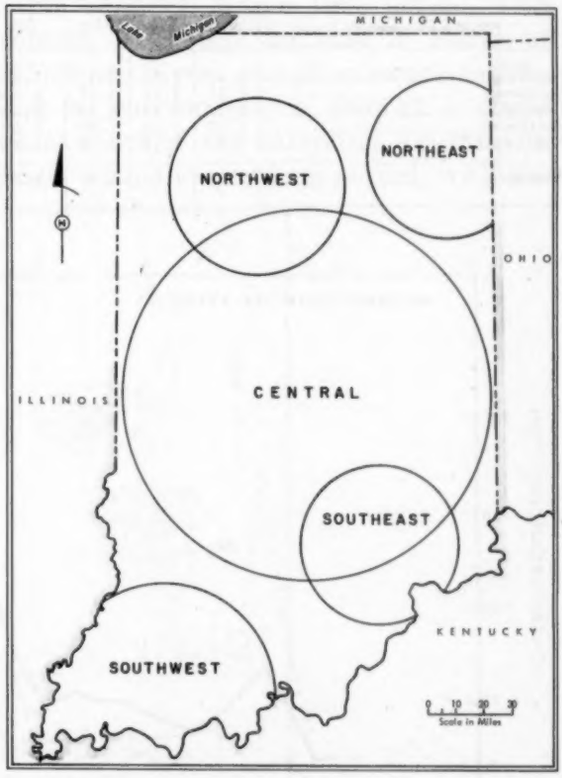

Figure 6. Indiana milk sampling locations

Analytical procedures

Strontium–89 and strontium–90 concentrations in milk samples are determined by ion exchange separation (*4, 5*) and subsequent low-background beta counting. The limits of detectability for strontium–89 and strontium–90 are 5 and 1 pCi/liter, respectively. Cesium–137, iodine–131, and barium–140 are determined by gamma spectroscopy. The counting system consists of a 512-channel pulse height analyzer and a shielded 4 x 4-inch sodium iodide crystal detector. The limit of detectability for both barium–140 and iodine–131 is 5 pCi/liter. Cesium–137 concentrations are subject to a 6 percent error at 100 pCi/liter.

Results and discussion

The monthly radionuclide concentrations in Indiana pasteurized milk are presented by station in table 6 for January through March 1965. The monthly concentrations of iodine–131 and barium–140 remained below limits of detectability.

The monthly network average concentrations of strontium–89, strontium–90, and cesium–137 are presented graphically in figure 7. Strontium–89 concentrations increased in the spring of 1962 following atmospheric nuclear testing. Subsequently these levels decreased until by the end of 1963 they were below detectable levels. Strontium–90 and cesium–137 concentrations also increased following 1962 atmospheric nuclear testing to a peak in the summer of 1963. With the subsequent cessation of atmospheric nuclear testing, these levels began a downward trend which has continued to date.

During the period covered, concentrations did not reach levels that required countermeasures based upon health implications. Criteria for such remedial action have been outlined by the Federal Radiation Council (*6*).

Table 6. Radionuclide concentrations in Indiana milk, January–March 1965

Sampling location	Calcium, g/liter			Potassium-40, pCi/liter			Strontium-89 pCi/liter			Strontium-90 pCi/liter			Cesium-137, pCi/liter		
	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar
Northeast	1.11	1.15	1.15	1,260	1,290	1,340	0	0	0	13	13	14	70	70	70
Southeast	1.21	1.17	1.17	1,330	1,300	1,320	0	0	0	16	18	17	65	65	65
Central	1.17	1.17	1.15	1,350	1,320	1,320	0	0	0	16	12	13	65	65	70
Southwest	1.17	1.15	1.20	1,410	1,260	1,280	0	0	0	16	18	20	60	60	70
Northwest	1.17	1.17	1.17	1,360	1,330	1,360	0	0	0	19	15	17	70	70	80
Average	1.17	1.16	1.17	1,340	1,300	1,320	0	0	0	16	15	16	65	65	70

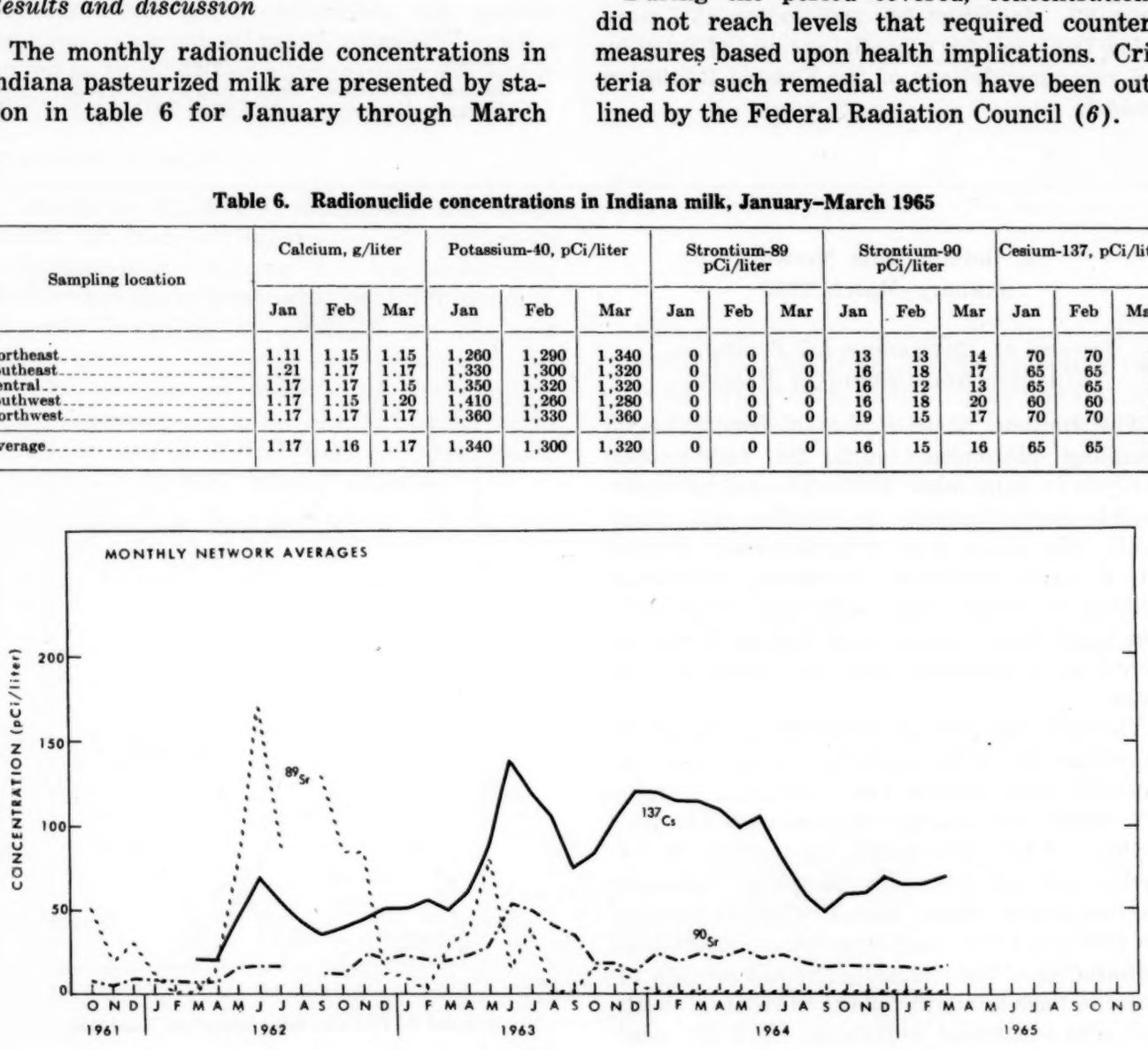

Figure 7. Radionuclide concentrations in Indiana pasteurized milk network

4. Oregon Milk Network January–March 1965

Division of Sanitation and Engineering
Oregon State Board of Health

The Oregon State Board of Health has monitored the concentrations of radionuclides in milk throughout Oregon on a continuing basis since the initiation of the milk surveillance program in March 1962. Milk samples are routinely collected at eight major production areas (figure 8), which supply 90 percent of milk distributed in the State.

Half-gallon samples of pasteurized packaged milk are collected monthly from milk-producing plants located in the eight milk-producing areas statewide by Oregon's Department of Agriculture. The Portland milk-producing area samples are collected weekly by the city of Portland. The Portland milk district sample is also analyzed under the USPHS Milk Surveillance Program on a weekly basis, with the results serving as a continuing interlaboratory reference. The milk sampling frequency is accelerated to a weekly basis in areas where iodine–131 concentrations exceed 100 pCi/liter, or where cesium–137 concentrations exceed 500 pCi/liter. The strontium–90 analyses are usually performed on a bimonthly schedule, but may be done monthly when significant increases are observed.

Analytical procedures

All milk samples are forwarded to and analyzed by the Oregon State Board of Health Environmental Radiation Laboratory. The concentrations of cesium–137, iodine–131, and barium-140 are determined by gamma spectrometry using a 3 x 3-inch scintillation detector with a 512-channel analyzer-computer. The strontium–90 concentrations are determined using a trichloroacetic acid analytical procedure (*7*), with the counting performed by means of a low-background counting system that includes a 2¼-inch detector.

The minimum detectable limits for determining the concentrations of the radionuclides cesium–137, iodine–131, and barium–140 are 15 pCi/liter; the limit for strontium–90 is 2 pCi/liter. The minimum detectable concentration is defined as the activity which is three times the standard deviation of the observed background activity.

Results and discussion

The cesium–137 concentrations at most of the sampling locations remained relatively stable during this January–March 1965 period, with the exception of a slight increase in March at the Medford and Nyssa sampling locations. The strontium–90 concentrations showed a slight decrease at most of the sampling locations in comparison with the previous period, with the

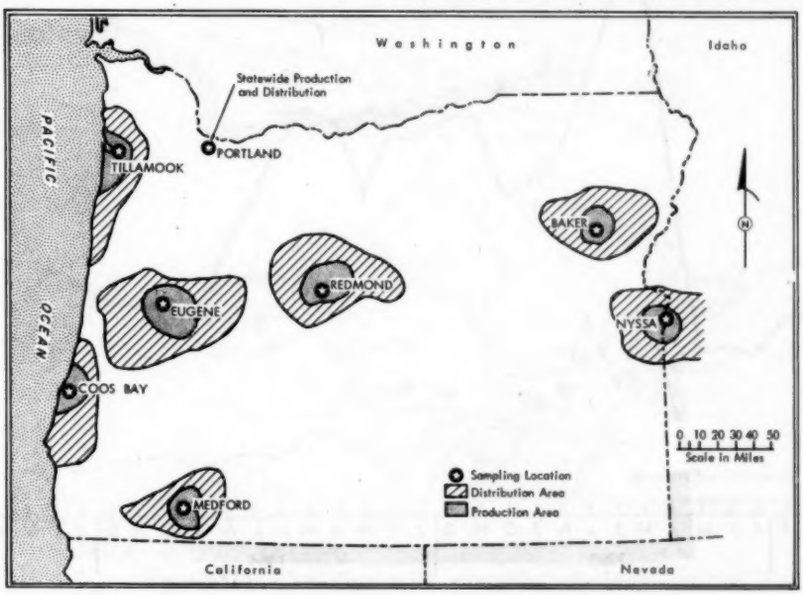

Figure 8. Oregon pasteurized milk network sampling locations showing production and distribution areas

exception of slight increases in the Portland and Baker areas. During this period iodine–131 and barium–140 concentrations remained below the minimum detectable limit of 15 pCi/liter. The results for the January–March 1965 period for all locations appear in table 7.

General trends for the levels of strontium–90 and cesium–137 can be observed from the concentrations representing the monthly network averages presented graphically in figure 9. The peak concentrations experienced in the spring of 1963 have shown a continual decrease, except for seasonal variations. This general trend can be expected to continue with the prolonged cessation of atmospheric nuclear testing.

The radonuclide concentrations in Oregon milk remain low in comparison to the recommendations of the Federal Radiation Council for remedial action based on health implications.

Table 7. Radionuclide concentrations in Oregon milk, January–March 1965

Sampling location	Sampling frequency	Strontium-90 (pCi/liter)			Cesium-137 (pCi/liter)		
		January	February	March	January	February	March
Baker	M	19	NA	22	75	80	85
Coos Bay	M	29	NA	27	165	150	140
Eugene	M	18	NA	13	85	60	70
Medford	M	14	NA	13	60	130	55
Nyssa	M	17	NA	13	105	70	50
Portland composite	W	15	22	22	88	120	98
Portland local	W	26	NA	33	113	102	108
Redmond	M	16	NA	NA	75	90	65
Tillamook	M	37	NA	28	145	125	130
Average		21		21	101	103	89

Symbol Legend— M—sampled monthly
W—sampled weekly
NS—no sample collected
NA—no analysis performed

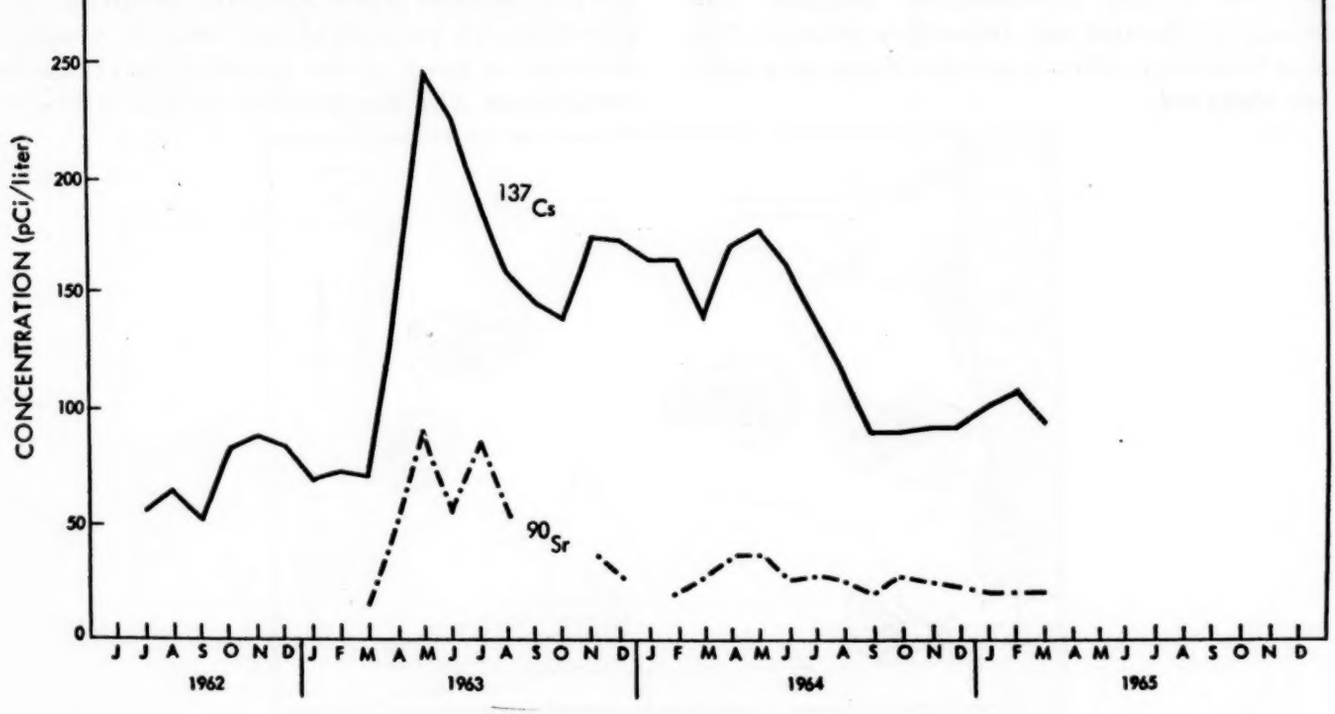

Figure 9. Radionuclides in Oregon milk network

5. Canadian Milk Network[3] April 1965

Radiation Protection Division, Department of National Health and Welfare, Ottawa, Canada

The Radiation Protection Division of the Department of National Health and Welfare began monitoring milk for strontium–90 in November 1955. At first, analyses were carried out on samples of powdered milk obtained from processing plants. However, since January 1963 liquid whole milk has been analyzed instead. With this change, more representative samples of milk consumed can be obtained, and milk sampling locations (see figure 10) can be chosen in the same areas as the air and precipitation stations. At present, the analyses include determinations of iodine–131, strontium–89, cesium–137, and strontium–90 as well as stable potassium and calcium.

The milk samples are obtained through the cooperation of the Marketing Division of the Canadian Department of Agriculture. At each station samples are collected three times a week from selected dairies, combined into weekly composites, and forwarded to the radiochemical laboratory in Ottawa. The contribution of each dairy to the composite sample is directly proportional to its volume of sales. In most cases a complete sample represents over 80 percent of the milk processed and distributed in the area. Several of the weekly samples are randomly selected and analyzed for iodine–131. The results of the spot checks for iodine–131 will not be reported unless there is evidence that the levels are rising. A monthly composite of the samples is analyzed for strontium–90, cesium–137, and stable potassium and calcium.

Analytical Methods

Radiochemical methods are used for the analysis of iodine–131 (*8*). For the analysis of radiostrontium, carrier strontium is added to a one-liter sample of milk, and the milk is then placed in a tray lined with a polyethylene sheet. The prepared sample is then dried under infrared lamps. The residue is ashed in a muffle furnace at 450°C., dissolved in dilute nitric acid, and strontium is separated by fuming nitric acid precipitation. The combined strontium–89 and strontium–90 are determined by counting in a low-background beta counter.

[3] This report was prepared from information and data in the May 1965 monthly report, "Data from Radiation Protection Programs", Canadian Department of National Health and Welfare, Ottawa, Canada.

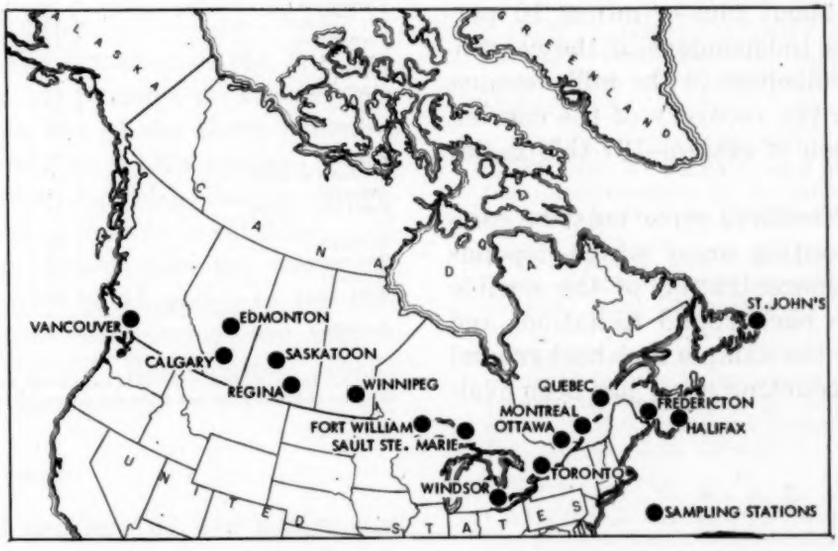

Figure 10. Canadian milk sampling stations

Strontium–90 is determined separately by extracting and counting its yttrium–90 daughter, while strontium–89 is estimated by difference from the total radiostrontium measurement. Appropriate corrections are made for self-absorption and counter efficiency at all stages. Calcium is determined by flame photometry.

Cesium–137 is determined by gamma spectroscopy using a scintillation crystal and a multi-channel pulse height analyzer. A sample consisting of 4.5 liters of milk is placed in a sample tray constructed in the form of an inverted well to accommodate the 5 x 4-inch sodium iodide crystal detector. The sample is counted for 100 minutes and the gamma spectrum is then recorded. Estimates are made of the potassium–40 and cesium–137 content of the milk by comparison of the spectrum with the spectra of standard preparations of these two radionuclides. With this method the potassium–40 concentration is determined and the Compton contribution of this radionuclide to the cesium–137 photopeak is subtracted to obtain the cesium–137 concentration. The stable potassium content is estimated from the potassium–40 concentration.

Sources of Error

In the iodine and strontium determinations, tests indicate that the statistical error (95 percent confidence level) in the chemical operations involved is about plus-or-minus 10 percent. This value is independent of the concentration of the radioisotope in the milk because it depends only on the recovery of the carrier. In the determination of cesium–137 this factor is not involved.

The chemical procedures error must be combined with the counting error which depends primarily on the concentration of the nuclide in the sample, the background radiation, and the length of time the sample and background are counted. This counting error has been evaluated mathematically for the particular counting arrangement used.

The overall errors, estimated on the basis indicated above, are given in table 8.

Table 8. Total error for various radionuclide concentrations in milk [a]

Nuclide	Error for 10 pCi/liter	Error for 50 pCi/liter	Error for 100 pCi/liter
Strontium-89	±25%	±20%	±15%
Strontium-90	±15%	±10%	±10%
Iodine-131	±50%	±20%	±10%
Cesium-137	±60%	±20%	±10%

[a] All errors are 2σ values, representing 95 percent confidence levels.

Results

Table 9 presents monthly averages of strontium–90, cesium–137, and stable calcium and potassium in Canadian whole milk. Spot checks for iodine–131 and strontium–89 indicate that all samples had insignificant levels of these radionuclides.

The results show that radionuclide concentrations in Canadian whole milk remained well below the levels permissible on health grounds.

Table 9. Radionuclides in Canadian whole milk, April 1965 [a]

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Calgary	1.17	1.6	23.5	104
Edmonton	1.15	1.7	24.8	113
Ft. William	1.11	1.7	40.1	179
Fredericton	1.15	1.7	34.3	178
Halifax	1.13	1.6	38.9	221
Montreal	1.13	1.7	27.6	156
Ottawa	1.10	1.7	22.7	109
Quebec	1.12	1.6	39.1	221
Regina	1.05	1.6	29.1	104
St. John's, Nfld	1.00	1.5	29.5	171
Saskatoon	1.18	1.7	29.9	110
Sault Ste. Marie	1.01	1.7	37.2	158
Toronto	1.09	1.7	12.6	81
Vancouver	1.15	1.6	32.8	217
Windsor	1.21	1.7	15.8	76
Winnipeg	1.00	1.7	29.0	133
Average	1.11	1.7	29.2	146

[a] Due to insignificant levels of iodine-131 and strontiun-89 the reporting of these radionuclides has been discontinued.

6. Pan American Milk Sampling Program April 1965

Pan American Health Organization, and *Public Health Service*

In accordance with a joint agreement, the PAHO (Pan American Health Organization) and the PHS (Public Health Service) developed a collaborative program for furnishing assistance to health authorities in the Americas engaged in developing programs in radiological health.

Under this agreement, the PHS Division of Radiological Health furnishes to PAHO, on a loan basis, limited quantities of essential items of equipment and the requisite laboratory services to establish a surveillance program.

Sampling procedures

Initially, air sampling stations were established in Chile, Jamaica, Peru, and Venezuela. In August 1963 the program was expanded to include a milk sampling station in Caracas, Venezuela. Between April 1964 and August 1964, additional stations were established in Jamaica at Kingston, Montego Bay, and Mandeville. Sampling varies according to local procedures.

Under the direction of the Venezuelan Institute for Scientific Investigation, weekly samples are collected, preserved with formaldehyde and composited monthly.

Jamaica, under the direction of the Ministry of Health, collects one monthly composite on a rotating basis from one of the three principal milk areas: Montego Bay (Montpelier), Mandeville, and Kingston (Spanish Town). To reduce spoilage it was necessary to establish cooling stations in the western parishes where the milk is received prior to shipping to the condensery in Kingston. All samples are sent to the PHS Southeastern Radiological Health Laboratory for analyses.

Analytical procedures

Iodine–131 and cesium–137 are determined by gamma scintillation spectrometry. Strontium–89, strontium–90 and barium–140 are determined radiochemically (*5*). Analytical errors are discussed in the "Analytical Procedures, Pasteurized Milk Network," page 423.

Data presentation

Table 10 presents stable calcium and potassium, strontium–89, strontium–90, and cesium–137 monthly average concentrations. The monthly average of iodine–131 and barium–140 concentrations in milk were less than 10 pCi/liter.

For comparison purposes, the radionuclide concentrations at Cristobal, Canal Zone, and San Juan, Puerto Rico are presented.

Table 10. Stable element and radionuclide concentrations in milk, April 1965

Sampling station	Calcium (g/liter)	Potassium (g/liter)	Strontium-89 (pCi/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Canal Zone: Cristobal	1.13	1.50	<5	4	40
Jamaica: Kingston	1.16	1.64	<5	11	145
Mandeville	* NS	NS	NS	NS	NS
Montego Bay	NS	NS	NS	NS	NS
Puerto Rico: San Juan	1.16	1.60	<5	10	50
Venezuela: Caracas	1.07	1.49	<5	4	25

* NS indicates no sample collected during this period.

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(*1*) PUBLIC HEALTH SERVICE. Summary of results from the raw milk sampling program, June 1957–April 1963. Rad Health Data 4:511–523 (October 1963).

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(*4*) PORTER, C., D. CAHILL, R. SCHNEIDER, P. ROBBINS, W. PERRY, and B. KAHN. Determination of strontium–90 in milk by an ion-exchange method. Anal Chem 33:676–678 (September 1961).

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(*7*) MURTHY, G. K., J. E. COAKLEY, and J. E. CAMPBELL. A method for the elimination of ashing in strontium–90 determinations in milk. J Dairy Sci 43:151–154 (1960).

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APPLICATION OF RADIONUCLIDE CONCENTRATIONS IN MILK TO INTAKE GUIDES, MAY 1964–APRIL 1965

Division of Radiological Health, Public Health Service

The concentrations of specific radionuclides in milk analyzed as part of the Pasteurized Milk Network (PMN) are reported on a monthly basis in *RHD*. In terms of radiological health surveillance activities, an important aspect of these data is the estimation of resultant radiation dose to population groups.

Approximate relationships between certain radionuclide intakes and dose have been applied to the formulation of daily intake guides (*1*) and permissible concentrations in selected environmental media (*2*). Although these guides are not themselves directly applicable to worldwide fallout, a comparison with environmental contamination levels does yield a measure of population dosage. In general, intake-dose and dose-biological effect relationships used in formulating the guides cited are based on continuous intake over an entire lifetime. However, for general surveillance purposes, yearly average intakes, used with discretion, may be compared directly with the levels adopted as lifetime intake guides. Thus, the radionuclide concentrations in milk, averaged over a year's time, together with milk consumption data, might be used in conjunction with the references cited above to approximate the radiation dose to a specific population group from a specific radionuclide. Table 1 presents annual averages of radionuclide concentrations in milk sampled by the PMN. Limited data are available for estimating the average daily milk consumption (on a volume basis) for specific age groups in the U.S. population (*3,4*).

Total dietary intake is of prime interest, and since the intake via milk consumption constitutes only a portion of the total radionuclide intake, the relationship of milk intake to total dietary intake is of importance in evaluating milk surveillance data. The Federal Radiation Council (*5*) notes: "A number of studies have shown that conservative estimates of the strontium–90 to calcium ratio in the total diet may be made by multiplying the ratio of strontium–90 to calcium in milk in a particular locality by 1.5."[1] Thus, a rough index of the total dietary intake of strontium–90 on an annual basis may be made from PMN annual averages by using this factor and the assumptions of approximately 1.2 grams of calcium per liter in PMN samples and a 1.0 gram daily intake of calcium.

In the case of iodine–131, milk can be considered the major source because of the rapid distribution and consumption of fresh milk. With most other foods, normal processing and distribution allows time for this short-lived nuclide to decay to insignificant levels.

The situation with respect to strontium–89 is more complicated. Its half-life of some 50 days makes it difficult to estimate the relative contribution made by sources other than milk to the total dietary intake.

The relative contribution of milk to the total dietary intake of cesium–137 is not well defined and depends principally on the amount of freshly deposited cesium–137 on products used for human and animal consumption, and the progress of cesium–137 through the food chain.

The data in table 1 are calculated as follows: results from all samples collected in each week (Sunday through Saturday) are averaged, and the averages for all weeks terminating in each of twelve consecutive months are averaged to obtain the annual average.[2] To obtain the annual average daily intake (pCi/day) of radionuclides from milk, the annual average concentration values (pCi/liter) in table 1 must be multiplied by the annual average daily consumption (liters/day) of milk.

Monthly variations of radionuclide concentrations in milk are influenced by a number of combined causes such as meteorologic conditions and dairying practices, apart from considerations of the original sources of the radionuclides. The moving yearly average (table 1) obtained by updating the previous twelve-month average by one month, shows variations averaged over the year and tends to minimize purely seasonal variations.

REFERENCES

(*1*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961). Price 20 cents.

[1] This ratio may vary from 1 to 2, depending on changes in rate of fallout deposition and relative consumption of non-milk products whose contamination reflects temporal and local deposition patterns (*6*).

[2] Beginning with the October 1963 data, iodine–131 values of <10 pCi/liter are considered to be zero for averaging purposes; previously, 5 pCi/liter was used for calculating the averages.

Table 1. Average radionuclide concentrations in milk for the twelve-month periods, April 1964–March 1965 and May 1964–April 1965 [a] (pCi/liter)

Sampling locations		Strontium-89		Strontium-90		Iodine-131		Cesium-137	
		Apr 1964–Mar 1965	May 1964–Apr 1965	Apr 1964–Mar 1965	May 1964–Apr 1965	Apr 1964–Mar 1965	May 1964–Apr 1965	Apr 1964–Mar 1965	May 1964–Apr 1965
Ala:	Montgomery	3	3	21	21	0	0	69	66
Alaska:	Palmer	4	3	20	20	0	0	99	93
Ariz:	Phoenix	3	3	5	5	0	0	26	25
Ark:	Little Rock	3	3	41	40	1	1	93	86
Calif:	Sacramento	3	3	7	7	0	0	35	31
	San Francisco	3	3	9	8	0	0	38	36
C. Z:	Cristobal	3	3	5	5	0	0	48	47
Colo:	Denver	3	3	19	19	0	0	82	81
Conn:	Hartford	3	3	18	18	0	0	112	106
Del:	Wilmington	3	3	22	21	1	1	95	89
D. C:	Washington	3	3	19	19	0	0	67	64
Fla:	Tampa	3	3	15	15	0	0	222	217
Ga:	Atlanta	3	3	29	28	0	0	112	106
Hawaii:	Honolulu	3	3	12	12	0	0	74	72
Idaho:	Idaho Falls	4	3	25	23	0	0	127	117
Ill:	Chicago	3	3	18	18	0	0	94	91
Ind:	Indianapolis	3	3	19	19	1	1	79	75
Iowa:	Des Moines	4	3	24	24	0	0	71	68
Kans:	Wichita	3	3	20	20	0	0	56	54
Ky:	Louisville	3	3	27	26	0	0	64	59
La:	New Orleans	4	4	47	46	0	0	113	105
Maine:	Portland	3	3	27	26	1	1	166	161
Md:	Baltimore	3	3	21	21	0	0	77	72
Mass:	Boston	3	3	28	28	0	0	172	164
Mich:	Detroit	3	3	17	17	2	2	93	90
	Grand Rapids	3	3	20	20	1	1	103	99
Minn:	Minneapolis	5	4	29	28	0	0	110	105
Miss:	Jackson	3	3	39	37	0	0	82	76
Mo:	Kansas City	4	4	25	25	0	0	63	58
	St. Louis	4	3	21	20	0	0	62	58
Mont:	Helena	3	3	21	21	1	1	123	114
Nebr:	Omaha	3	3	23	23	0	0	73	68
Nev:	Las Vegas	3	3	8	8	1	1	57	54
N. H:	Manchester	3	3	27	27	1	1	191	183
N. J:	Trenton	3	3	18	18	1	1	94	89
N. Mex:	Albuquerque	3	2	11	11	1	1	50	47
N. Y:	Buffalo	3	3	19	18	0	0	115	112
	New York	3	3	23	23	1	1	124	117
	Syracuse [b]	3	3	17	17	0	0	108	103
N. C:	Charlotte	3	3	36	35	0	0	93	88
N. Dak:	Minot	8	7	53	53	0	0	137	134
Ohio:	Cincinnati	3	3	20	19	0	0	73	69
	Cleveland	3	3	20	20	0	0	97	94
Okla:	Oklahoma City	3	3	21	21	0	0	57	54
Ore:	Portland	5	4	28	27	0	0	135	128
Pa:	Philadelphia	3	3	19	19	0	0	93	87
	Pittsburgh	3	3	28	27	0	0	122	117
P. R:	San Juan	3	3	12	12	0	0	66	62
R. I:	Providence	3	3	22	21	0	0	129	123
S. C:	Charleston	3	3	31	31	0	0	110	107
S. Dak:	Rapid City	4	4	37	36	0	0	132	130
Tenn:	Chattanooga	3	3	38	36	0	0	92	85
	Memphis	3	3	30	29	0	0	57	54
Tex:	Austin	3	3	8	8	0	0	34	33
	Dallas	3	3	18	18	0	0	48	47
Utah:	Salt Lake City	5	5	24	23	0	0	143	136
Vt:	Burlington	3	3	24	24	2	2	140	133
Va:	Norfolk	3	3	18	18	0	0	77	74
Wash:	Seattle	5	5	27	27	0	0	137	133
	Spokane	5	4	26	26	0	0	121	116
W. Va:	Charleston	3	3	23	22	0	0	58	55
Wis:	Milwaukee	3	3	16	16	1	1	106	101
Wyo:	Laramie	5	4	18	18	0	0	89	86
Network average		3	3	22.4	22.0	0	0	95	91

[a] Annual averages were computed on basis of 52 weekly averages. Annual averages for barium-140 at each station were <10.
[b] Annual averages were computed on basis of 48 weekly averages.

(2) NATIONAL COMMITTEE ON RADIATION PROTECTION. Maximum permissible body burdens and maximum permissible concentrations of radionuclides in air and in water for occupational exposure, National Bureau of Standards Handbook 69, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (June 5, 1959).

(3) BUREAU OF CENSUS and PUBLIC HEALTH SERVICE. National Food Consumption Survey, fresh whole milk consumption in the United States, July 1962. Rad Health Data 4:15–17 (January 1963).

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(5) FEDERAL RADIATION COUNCIL. Estimates and evaluation of fallout in the United States from nuclear weapons testing conducted through 1962, Report No. 4. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1963).

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EFFECT OF VARIETY ON THE ACCUMULATION OF STRONTIUM-90 IN WHEATS AND THEIR MILLED PRODUCTS

R. A. Anderson and V. F. Pfeifer[1]

Strontium–90 levels in wheats grown in various parts of the United States have been reported for 1963 (*1*) and 1964 (*2*). At the U. S. Department of Agriculture's Northern Regional Research Laboratory, methods are being developed to reduce the radionuclide content of wheats and their milled products. Should a need ever arise for such a process, procedural details would be immediately available.

Information is needed on the effects of variety on uptake of strontium–90 from fallout and by absorption from soil. Rasmusson, Smith, and Myers (*3*) have shown that specific varieties can be selected that minimize uptake by absorption from soil alone. In collecting the 1964 hard red winter (HRW) wheat samples, a series was obtained covering 6 varieties each grown at 5 locations in Kansas, and a series covering a total of 10 varieties grown at 2 locations in Nebraska. These samples permitted: (1) a comparison of differences in strontium–90 uptake by wheat varieties planted in identical soil and grown under identical conditions; (2) a determination as to whether or not the effects of varietal differences extended to other locations in which different sets of growing conditions prevailed; and (3) a comparison of milled products from varieties grown in one location under identical growing conditions, but exhibiting high and low levels of strontium–90 uptake.

Materials

Ten-pound wheat samples representative of the production from large test plots were obtained from five Kansas State University experimental farms. Each farm furnished samples of the following six varieties: Bison, Kaw, Ottawa, Scout, Triumph, and Turkey. The Garden City Station furnished samples from both irrigated and dry-land production. Ten-pound samples were also obtained of 10 different varieties representative of large test plots of the University of Nebraska experimental farms. Five of these were from Lincoln, and five from Alliance.

Procedures

Each lot of wheat was mechanically cleaned in a dockage tester before analysis or milling in order to remove dust and chaff. The wheats were milled in a Buhler experimental flour mill.[2] Strontium–90 was determined by a modification of the method of Harley (*4*). Analyses for protein, ash, and calcium were made by Cereal Laboratory Methods 46–10, 08–01, and 40–20, respectively (*5*).

Results and Discussion

Levels of strontium–90 in the Kansas wheats are given in table 1. Based on the mean values for each variety, uptake of strontium–90 by these wheats was in the following order: Ottawa (highest), Triumph, Kaw, Scout, Bison, and Turkey (lowest). Statistical analysis of these results indicated that uptake by the first three varieties (Ottawa, Triumph, Kaw) was significantly different than by the other three varieties (Scout, Bison, Turkey). As is apparent from table 1, location was a highly significant source of variation.

Strontium–90 in the Nebraska wheats is listed in table 2. The averages for Lincoln and Alliance are 226 and 81 pCi/kg, respec-

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[2] Mention of firm names or trade products does not imply that they are endorsed or recommended by the Department of Agriculture over other firms or similar products not mentioned.

tively; the large difference is due, at least in part, to the much higher rainfall during May and June in Lincoln. As with the Kansas wheats, Ottawa took up the largest amount of strontium–90 in the five varieties grown at Lincoln, and Bison, the lowest amount. Scout, which was in the lower group of Kansas wheats, was also slightly below the average for the five varieties grown at Alliance.

Results of milling experiments carried out with Ottawa and Turkey HRW wheats, the varieties exhibiting highest and lowest uptake of strontium–90, are given in table 3. Both wheats were grown at Manhattan, Kansas. Each was milled under such conditions that yields of feeds and flours would be similar. The chief differences between the fractions from the two varieties were in the shorts and bran; the flours were about the same. This comparison is shown best in the last column of table 3, which lists the contribution of each fraction to the total strontium–90 present in a kilogram of wheat milled. Nearly equal amounts of strontium–90 were present in the endosperm (flour) fractions, but the outer layers of the Ottawa wheat (bran and shorts) contained nearly 50 percent more than those of the Turkey wheat. These results suggest that the two varieties differ markedly in the amounts of strontium–90 taken up from fallout.

Results reported here indicate that specific wheat varieties can be grown to minimize uptake of strontium–90 from fallout and by absorption from soil. Apparently, considerable differences in uptake from fallout alone are exhibited by different varieties grown under identical conditions. These differences are probably due to slightly different agronomic properties of the wheats, such as heading and ripening, as well as to structural differences in the kernels and glumes. Growing only varieties that take up minimum amounts of strontium–90 from fallout and by absorption from soil, in combination with the removal of the bulk of the contamination by means of effective milling, should ensure foods of the lowest possible contamination under conditions of high-density fallout.

Table 1. Strontium-90 in 1964 hard red winter wheat grown at five locations in Kansas

(pCi/kg calculated on dry basis)[a]

Variety	Location						
	Manhattan	Hays	Garden City		Hutchinson	Newton	Variety mean
			Irrigation	Dry land			
Bison	297	217	159	128	104	197	184
Kaw	289	237	173	179	149	275	217
Ottawa	380	299	230	179	163	239	248
Scout	297	202	190	145	136	187	193
Triumph	334	250	152	193	146	261	223
Turkey	263	188	[b] —	131	131	198	182
Location mean	310	232	181	159	138	226	

[a] Wheat moisture varied from 9.6 to 12.9 percent.
[b] Dash indicates no analysis was done.

Table 2. Strontium-90 in 1964 hard red winter wheat grown at two locations in Nebraska

(calculated on dry basis)[a]

Variety grown in Lincoln	Nitrogen (percent)	Ash (percent)	Calcium (percent)	Strontium-90 (pCi/kg)	Variety grown in Alliance	Nitrogen (percent)	Ash (percent)	Calcium (percent)	Strontium-90 (pCi/kg)
Bison	2.58	1.94	0.050	175	Cheyenne	3.14	1.65	0.047	71
Gage	2.94	1.94	0.055	210	Lancer	2.69	1.57	0.042	90
Omaha	2.95	1.86	0.064	235	Nebred	2.62	1.66	0.046	94
Ottawa	2.79	2.02	0.049	282	Scout	2.79	1.56	0.042	77
Pawnee	2.75	1.80	0.052	226	Warrior	3.17	1.66	0.049	71

[a] Wheat moistures varied from 10.6 to 11.9 percent.

Table 3. Strontium-90 in milled products from Ottawa and Turkey 1964 wheats grown near Manhattan, Kansas

(analyses on dry basis)

Fraction	Yield (percent)	Nitrogen (percent)	Ash (percent)	Calcium (percent)	Strontium-90 (pCi/kg)	Strontium-90 in fraction (percent of total)	Strontium-90 in fraction (pCi/kg of milled wheat)
Ottawa variety HRW wheat							
Wheat	—	3.21	1.80	0.054	380	—	—
Long patent flour	64.6	3.08	0.47	0.022	44	7.4	29
Clear flour	9.4	3.36	1.02	0.031	80	2.0	8
Shorts	8.5	3.99	4.58	0.132	916	20.0	78
Bran	17.5	3.72	6.15	0.158	1,570	70.6	274
Total	100					100	389
Turkey variety HRW wheat							
Wheat	—	3.17	1.81	0.051	263	—	—
Long patent flour	65.9	2.88	0.53	0.025	40	9.7	27
Clear flour	10.1	3.38	1.13	0.037	79	2.9	8
Shorts	7.5	3.55	4.63	0.117	645	17.7	48
Bran	16.5	3.66	6.18	0.137	1,160	69.7	191
Total	100					100	274

Acknowledgments

We are grateful to E. G. Heyne, Kansas State University, Manhattan, Kansas, for supplying the 41 Kansas wheats; and to V. A. Johnson, Crops Research Division, USDA, Lincoln, Nebraska, for supplying the 10 Nebraska wheats.

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STRONTIUM-90 CONTENT OF HUMAN FOOD AND ANIMAL FEED, 1962–1964

Division of Pharmacology
Food and Drug Administration

This report is a resume of the strontium–90 content of selected human foods and one kind of animal feed for the three harvest years 1962, 1963 and 1964. Because of a considerably smaller number of samples collected in 1964, only a limited number of products can be examined for later geographical and temporal trends. Assessments made for years 1962 and 1963 have previously been reported (*1*).

With the addition of the results from 1964 it is now possible to make a judgment that a downward trend in strontium–90 has started, having begun most probably in the latter part of 1964. The decline is slow, and the indications are that levels of strontium–90 in crops such as wheat, tea, alfalfa and dairy products may maintain sizeable levels for several years to come.

Results

In table 1 are shown the strontium–90 contents of 18 products harvested in the years under study. The data have been tabulated in order of decreasing levels of the nuclide, with no attempt at identification of geographical areas. The same results are shown graphically in figure 1. Without exception, all products exhibited lowest levels of strontium–90 in 1962 and elevation of these levels either in 1963 or 1964. Peak values are about equally distributed in these two years, but in the case of alfalfa and wheat the most decisive peak occurred in 1963. Because alfalfa, wheat, powdered milk, leafy vegetables and root crops constitute a sizeable proportion of the food chain, the declining strontium–90 levels (except cabbage) of these products in 1964 make it likely that the general dietary intake of this nuclide is on the decline.

In table 2 are shown by area the strontium–90 concentrations of 8 products averaged over the years 1962 through 1964. The results show that the highest concentrations of strontium–90 occurred in the Central States (with the exception of cabbage and carrots), next in order (with the exception of spinach) in the Eastern States, and lowest in the Western States.

Table 1. The strontium-90 content of foodstuffs harvested in 1962–1964

Product	1962			1963			1964		
	Strontium-90, pCi/kg		Number of samples	Strontium-90, pCi/kg		Number of samples	Strontium-90, pCi/kg		Number of samples
	Average	Range		Average	Range		Average	Range	
Alfalfa	447	21 —1,700	100	2,190	35 —4,280	118	792	92 —3,340	24
Cabbage	14	0.3—68	127	16	0.4—153	60	32	0.7—145	21
Carrots	7.6	0.3—5	79	17	0.4—64	43	8.7	1.8—25	8
Celery	12	0.7—60	74	19	0.9—118	66	14	5.3—43	8
Cheese	85	18 —281	39	189	12 —689	47	218	14 —783	23
Coffee	16	0.9—90	114	47	1.7—267	41	56	5.0—195	25
Lettuce	17	0.1—178	125	22	1.1—141	127	18	0.7—771	33
Oranges	9.3	1.5—27	13	11	1.9—29	3	21	4.3—38	4
Potatoes	2.3	0.0—6.4	75	11	0.3—157	44	9.5	1.2—21	14
Powdered milk	158	4.8—1,040	33	226	6.2—736	84	207	3 —949	67
Snap beans	20	0.0—80	63	36	2.3—159	81	28	1.0—84	18
Soy beans	75	1.2—693	62	100	2.7—598	75	121	18 —506	9
Spinach	57	5.3—198	36	89	3.1—228	44	56	5.4—162	27
Strawberries	14	0.8—42	21	32	2.7—102	45	41	1.7—129	35
Tea	386	19 —2,290	158	1,010	39 —4,340	55	1,030	42 —7,590	33
Tomatoes	2.6	0.0—9.0	64	6.0	0.0—38	24	2.8	0.6—4.0	4
Tuna fish	0.3	0.0—2.8	35	0.6	0.1—2.5	20	2.3	1.3—5.3	12
Wheat	90	1.4—495	127	260	4 —1,340	123	123	9.7—261	55

Table 2. Geographic distribution of strontium-90 content in raw agricultural products harvested during 1962, 1963 and 1964

	Western States [1]		Central States [2]		Eastern States [3]	
	Av. conc. ^{90}Sr, pCi/kg	Number of samples	Av. conc. ^{90}Sr, pCi/kg	Number of samples	Av. conc. ^{90}Sr, pCi/kg	Number of samples
Alfalfa	418	68	907	103	704	71
Wheat	70	79	204	190	124	47
Spinach	85	31	98	26	57	40
Lettuce	12	126	38	37	23	122
Strawberries	5.3	19	38	48	36	34
Cabbage	7.2	50	17	75	24	73
Carrots	3.8	50	11	39	19	37
Potatoes	2.0	34	8.9	46	6.8	43

[1] *Western States*
Arizona
California
Colorado
Idaho
Montana
Nevada
New Mexico
Oregon
Utah
Washington
Wyoming

[2] *Central States*
Alabama
Arkansas
Illinois
Indiana
Iowa
Kansas
Kentucky
Louisiana
Michigan
Minnesota
Mississippi
Missouri
Nebraska
North Dakota
Ohio
Oklahoma
South Dakota
Tennessee
Texas
Wisconsin

[3] *Eastern States*
Connecticut
Delaware
Florida
Georgia
Maryland
Maine
Massachusetts
New Hampshire
New Jersey
New York
North Carolina
Pennsylvania
Rhode Island
South Carolina
Vermont
Virginia
West Virginia

Table 3 shows the results broken down by year. It can be seen that in the Western and Central States the year 1963 produced the greatest preponderance of higher concentrations of strontium–90, when compared with the 1962 values for that area. In the Eastern States, 5 products (wheat, cabbage, spinach, strawberries and snap beans) reached their highest levels in 1964 compared with 1962 values for that area. It should be emphasized that because of the wide range of values from which averages are calculated, only trends, and not statistical significance at the customary 5 percent level, should be inferred from these results.

Within the frame of reference indicated by the Federal Radiation Council (*2*) no foods reached levels of strontium–90 that would have required protective action such as special processing or substitution to lower the daily intake of this nuclide.

Table 3. Average content of strontium-90 in raw agricultural products by year and area (pCi/kg)

Product	Western States [1]			Central States [2]			Eastern States [3]		
	1962	1963	1964	1962	1963	1964	1962	1963	1964
Alfalfa	186	445	917	532	1,210	1,080	559	973	230
Apples	0.9	4.0	2.6	2.8	11	NS	3.0	9.4	NS
Cabbage	5.0	8.0	18	11	20	18	20	23	76
Carrots	2.3	7.1	3.4	8.5	18	7.1	15	24	21
Celery	4.7	13	7.8	7	20	NS	17	23	21
Lettuce	11	14	12	22	57	42	20	28	16
Peaches	1.7	5.1	NS	9.4	25	NS	5.1	17	NS
Potatoes	1.0	4.4	1.8	2.8	12	10	2.9	13	12
Snap Beans	4.9	11	NS	22	50	18	30	40	50
Spinach	77	88	27	72	114	99	33	71	75
Strawberries	3.0	9.1	6.8	26	35	45	21	35	46
Tomatoes	0.5	2.6	NS	2.2	4.9	NS	4.9	14	2.8
Wheat	30	128	78	107	341	134	93	137	147

[1] [2] [3] States grouped as in table 2.
NS indicates no sample collected.

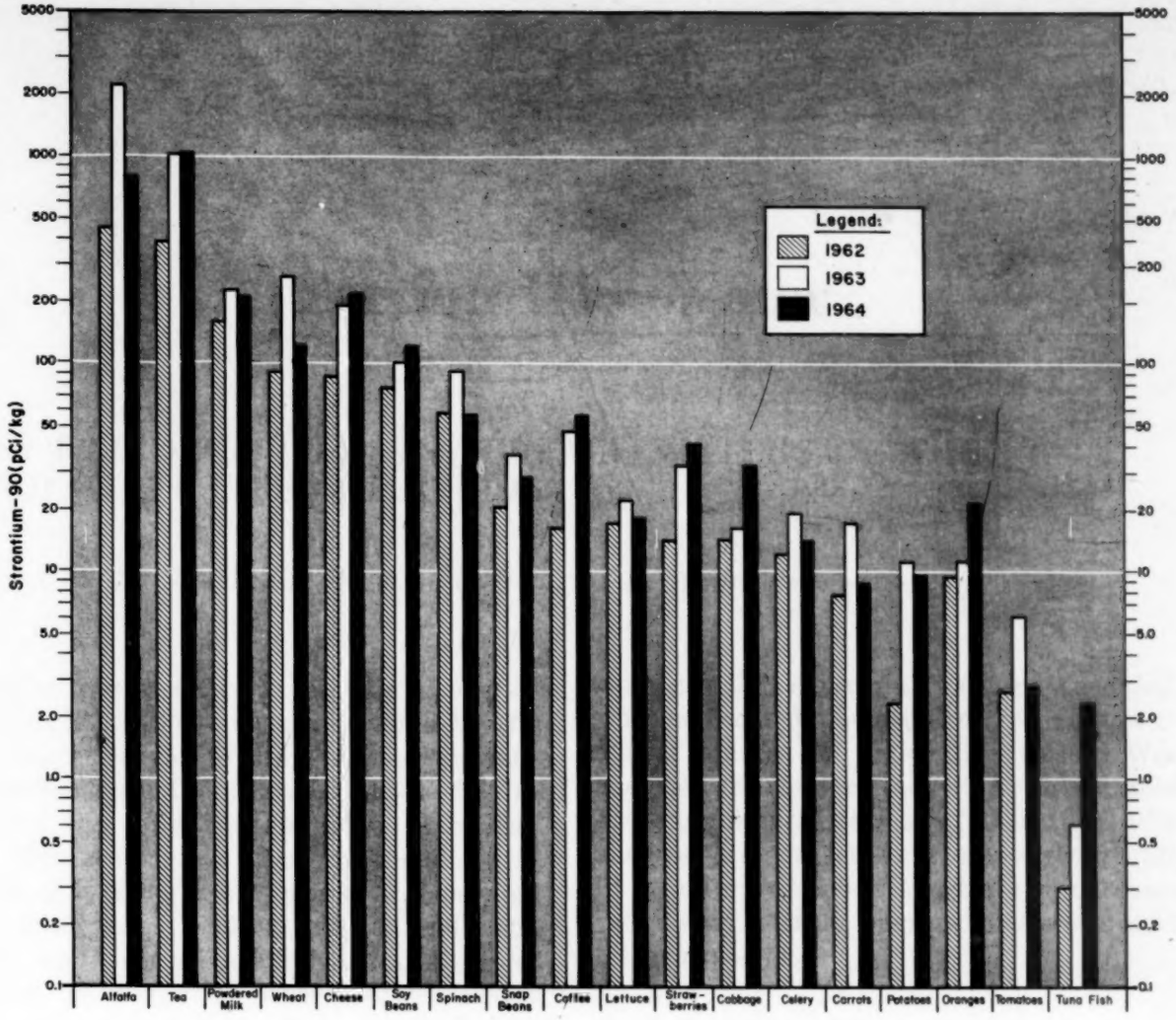

Figure 1. Average strontium–90 contents of foodstuffs, 1962–1964

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Section III—Water

GROSS RADIOACTIVITY IN SURFACE WATERS OF THE UNITED STATES, FEBRUARY 1965

Division of Water Supply and Pollution Control, Public Health Service

Levels of radioactivity in surface waters of the United States have been monitored by the Public Health Service Water Pollution Surveillance System since its initiation in 1957. Beginning with the establishment of 50 sampling points, this system has been expanded to include 131 stations. These stations are operated jointly with other Federal, State, and local agencies, and with private industries. Samples are taken from surface waters of all major U.S. river basins for physical, chemical, biological, and radiological analyses. The system provides background information necessary for recognizing water quality trends and for determining current and general levels of surface water contamination and early detection of specific situations which may warrant more detailed evaluation. Data assembled through the system and exact locations of sampling points are published in annual compilations (*1–8*).

Sampling procedures

The participating agencies collect one-liter "grab" samples each week and ship them "as is" to the Surveillance System Laboratory in Cincinnati for analysis. Gross alpha and gross beta radioactivity determinations on the suspended and dissolved solids are performed as frequently as deemed necessary. Presently, gross alpha and beta determinations are made either on monthly composites of the weekly samples or on each weekly sample. Weekly alpha and beta determinations are scheduled for stations located downstream from known potential sources of radioactive waste. Weekly analyses are conducted at all newly established stations for the first year of operation. Weekly analyses are also scheduled for selected stations in an effort to detect short term increases in radioactivity from current or recent nuclear tests or events.

Analytical methods

The analytical method for determining gross alpha and beta radioactivity is described in the eleventh edition of "Standard Methods for the Examination of Water and Wastewater" (*9*). Suspended and dissolved solids are separated by passing the sample through a membrane filter (type HA) with a pore size of 0.45 micron. Planchets are then prepared for counting the dissolved solids (in the filtrate) and the suspended solids (on the charred membrane filter) in an internal proportional counter. Reference sources of U_3O_8, which give a known count rate if the instrument is performing properly, are used for daily checking of the counter.

Normally, samples are counted within two weeks following collection or within one week after compositing. The decay of activity is followed for each sample for which the first analysis shows unusually high activity. Also, if a recount indicates that the original analysis was

questionable, values based on recounting are recorded. All results are reported for the time of counting and are not extrapolated to the date of collection.

Results

Table 1 presents the most recent results of alpha and beta analysis of U. S. surface waters. The stations on a river are arranged in the table according to their relative locations, the first stations listed being closest to the headwaters. These data are preliminary. The figures for gross alpha and gross beta radioactivity represent either determinations on composite samples or means of weekly determinations where composites were not made. The monthly means are reported to the nearest pCi/liter. When all samples have zero pCi/liter, the mean is reported as zero; when the calculated mean is between zero and 0.5, the mean is reported as <1 pCi/liter.

A geographical perspective of the radioactivity in surface water is obtained from the numbers printed near the stations as shown in figure 1, which gives the average total beta activity in suspended-plus-dissolved solids in raw water collected at each station. Gross radioactivity results for the years 1957–1962 have been summarized by Weaver *et al* (*10*).

It has been observed that in water the natural environmental beta activity is usually several times that of the natural environmental alpha activity. Nuclear installations may contribute additional alpha and/or beta activity whereas fallout primarily contributes additional beta activity.

Table 1. Radioactivity in raw surface waters, February 1965
(Average concentrations in pCi/liter)

Station	Beta activity			Alpha activity		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Animas River:						
Cedar Hill, N. Mex.	13	13	26	4	3	7
Arkansas River:						
Coolidge, Kans.	6	118	124	1	40	41
Ponca City, Okla.	2	14	16	0	2	2
Atchafalaya River:						
Morgan City, La.	173	11	184	62	1	63
Bear River:						
Preston, Idaho	1	18	19	1	3	4
Big Horn River:						
Hardin, Mont.	8	20	28	3	7	10
Chena River:						
Fairbanks, Alaska	2	6	8	1	0	1
Clearwater River:						
Lewiston, Idaho	5	7	12	<1	0	<1
Clinch River:						
Clinton, Tenn.	0	5	5	0	0	0
Kingston, Tenn.	4	31	35	0	0	0
Colorado River:						
Loma, Colo.	4	13	17	1	2	3
Page, Ariz.	1	34	35	0	9	9
Parker Dam, Calif-Ariz.	0	14	14	0	10	10
Columbia River:						
Pasco, Wash.	55	260	315	0	1	1
Clatskanie, Ore.	19	47	66	1	1	2
Wenatchee, Wash.	1	16	17	0	1	1
Connecticut River:						
Enfield Dam, Conn.	1	7	8	0	0	0
Coosa River:						
Rome, Ga.	4	5	9	0	0	0
Cumberland River:						
Cheatham Lock, Tenn.	2	5	7	1	0	1
Delaware River:						
Philadelphia, Pa.	3	7	10	0	0	0
Great Lakes:						
Duluth, Minn.	0	4	4	0	0	0
Green River:						
Dutch John, Utah	1	25	26	0	3	3
Hudson River:						
Poughkeepsie, N.Y.	3	8	11	0	0	0
Kansas River:						
De Soto, Kans.	10	18	28	2	2	4
Klamath River:						
Keno, Oreg.	4	10	14	0	<1	<1
Maumee River:						
Toledo, Ohio	17	17	34	3	2	5
Mississippi River:						
New Roads, La.	21	9	30	6	1	7
New Orleans, La.	15	9	24	4	0	4
St. Paul, Minn.	1	16	17	0	1	1
Missouri River:						
Williston, N. Dak.	7	36	43	0	7	7
Bismarck, N. Dak.	2	24	26	0	3	3
St. Joseph, Mo.	19	21	40	3	4	7
North Platte River:						
Henry, Nebr.	2	68	70	0	56	56
Ohio River:						
Cairo, Ill.	22	8	30	9	0	9
Toronto, Ohio	5	6	11	1	0	1
Pend Oreille River:						
Albeni Falls Dam, Idaho	1	5	6	0	1	1
Platte River:						
Plattsmouth, Nebr.	24	25	49	4	4	8
Potomac River:						
Washington, D.C.	19	5	24	7	0	7
Rainy River:						
Baudette, Minn.	1	24	25	0	<1	<1
Red River, North:						
Grand Forks, N. Dak.	1	27	28	0	3	3
Red River, South:						
Alexandria, La.	57	17	74	20	0	20
Rio Grande:						
El Paso, Tex.	4	10	14	0	3	3
Laredo, Tex.	4	14	18	0	6	6
San Joaquin River:						
Vernalis, Calif.	2	6	8	1	1	2
San Juan River:						
Shiprock, N. Mex.	58	16	74	22	3	25
Savannah River:						
Port Wentworth, Ga.	4	9	13	<1	0	<1
Snake River:						
Wawawai, Wash.	4	8	12	3	1	4
Payette, Idaho	2	10	12	1	2	3
South Platte River:						
Julesburg, Colo.	14	87	101	4	53	57
Tennessee River:						
Chattanooga, Tenn.	1	8	9	0	0	0
Wabash River:						
New Harmony, Ind.	20	53	73	2	1	3
Yellowstone River:						
Sidney, Mont.	8	14	22	3	5	8
Minimum	0	4	4	0	0	0
Maximum	173	260	315	62	56	63

[a] These data are preliminary: reanalysis of some samples may be made and additional analyses not completed at the time of this report may become available. For final data, one should consult the system's annual report.

Figure 1. Sampling locations and associated total beta activity (pCi/liter) in surface waters, February 1965

The radioactivity associated with dissolved solids provides a rough indication of the levels which would occur in treated water, since nearly all suspended matter is removed by treatment processes (*11*). The Public Health Service Drinking Water Standards state that when unidentified alpha emitters and strontium–90 do not exceed specific limits of 3 pCi/liter and 10 pCi/liter, respectively, a water supply is acceptable when the gross beta concentration does not exceed 1,000 pCi/liter (*12*).

The rise of radioactivity levels expressed in pCi/liter at a particular station is often presumed to be associated with a corresponding increase in suspended solids. For example, the samples for November 1964, January and February 1965, from the Atchafalaya River at Morgan City, Louisiana, have shown increased alpha and beta activities for suspended solids when compared to results of other recent months. In order to verify and understand the meaning of these results, several steps were taken. Data from the nearest upstream station (Alexandria) was also examined. The results over the five-month period from October 1964 through February 1965 were: average volumetric alpha activity, 46 pCi/liter of suspended solids; and average beta activity, 178 pCi/liter of suspended solids.

A three-month composite of weekly samples collected at Morgan City during the period October through December 1964 was analyzed in triplicate in order to verify the monthly determinations. The average volumetric alpha activity for suspended solids was 53 pCi/liter and the average volumetric beta activity for suspended solids was 147 pCi/liter. The agreement between determinations was excellent, and agreement with the five-month averages at Morgan City and Alexandria was reasonable.

Although noticeable variations occurred in the volumetric radioactivity values, the specific radioactivity values in pCi/g of suspended solids did not show the same degree of change. Thus, the rise observed in the values presented in pCi/liter is obviously associated with the level of suspended solids in the water. The alpha and beta activities of the dissolved solids also show the same pattern but in lesser degree.

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(*1*) DIVISION OF WATER SUPPLY AND POLLUTION CONTROL, PUBLIC HEALTH SERVICE. National water quality network annual compilation of data. PHS Publication No. 663, 1958 Edition, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Price $1.50.

(*2*) *Ibid.*, 1959 Edition. Price $1.75.

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(*4*) *Ibid.*, 1961 Edition.[1]

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(*7*) *Ibid.*, 1964 Edition (in preparation).

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[1] Single free copies of this publication may be obtained from Public Inquiries Branch, Public Health Service, U.S. Department of Health, Education, and Welfare, Washington, D.C. 20201.

RADIOACTIVITY IN MINNESOTA MUNICIPAL WATER SUPPLIES,[1] JULY-DECEMBER 1964

Division of Environmental Sanitation
Minnesota Department of Health

The analysis of various Minnesota waters for radioactivity concentration was initiated in 1956 as part of the Minnesota Water Pollution Control Program. This program was expanded in 1958 to include most of the municipal surface water supplies in the State as well as selected lakes throughout the State.

As many as 25 surface streams and lakes involving 74 stations have been sampled. At present, six surface streams and lakes used as municipal water supplies are sampled routinely (figure 1). "Grab" samples of raw and treated water are collected weekly at each station. No raw water is collected from the Minneapolis supply.

The samples are forwarded to the Division's laboratory, where they are analyzed for gross beta activity. A 250-ml sample of water is transferred to a 2-inch planchet and evaporated at 75°C. The solid residue (suspended-plus-dissolved solids) is fixed by adding lucite in acetone. The sample is then counted for beta activity in an internal proportional counter. Counter standardization is accomplished by adding known amounts of thallium–204 standard to solutions containing the normal range of solids.

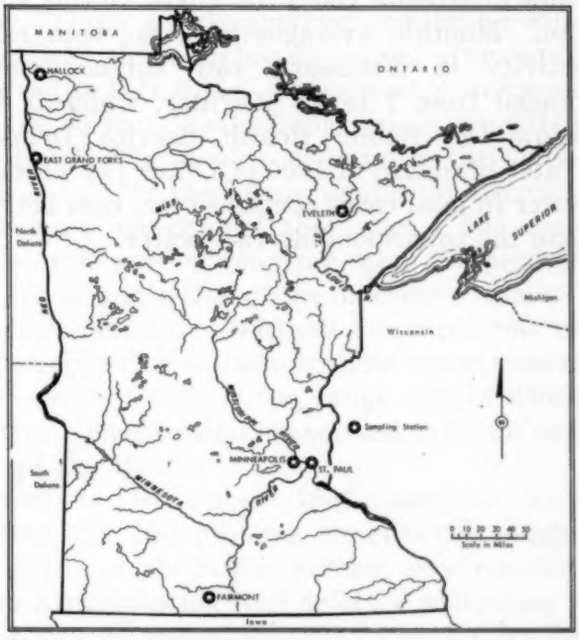

Figure 1. Minnesota surface water sampling locations

Table 1 shows a summary of the monthly average gross beta activity in Minnesota municipal water supplies from July–December 1964. The minimum reported level corresponding to an error of one standard deviation is 15 pCi/liter at present. In averaging, the value 7 pCi/liter is used for samples having less than the minimum detectable value.

[1] Data and information from "Survey of Environmental Radioactivity, July–December 1964." State of Minnesota Department of Public Health, University Campus, Minneapolis 14, Minnesota 55440, COO–651–10.

Table 1. Total beta concentrations in Minnesota raw and treated water supplies, July–December 1964

[Monthly average concentrations in pCi/liter]

Town and water source	Type of water	July	Aug	Sept	Oct	Nov	Dec
East Grand Forks, Red Lake River	Raw	54	64	27	28	32	29
	Treated	25	17	11	7	17	19
Eveleth, St. Mary's Lake	Raw	21	20	28	19	32	23
	Treated	24	23	9	14	16	21
Fairmount, Budd Lake	Raw	14	22	12	23	28	19
	Treated	9	13	27	11	7	16
Hallock, Two Rivers South Fork	Raw	64	43	46	37	46	40
	Treated	29	10	9	11	14	23
Minneapolis Tap Water	Raw	[a] NS	NS	NS	NS	NS	NS
	Treated	7	7	7	10	7	15
St. Paul, Vadnais Chain of Lakes	Raw	16	23	16	28	24	21
	Treated	7	12	9	7	13	14

[a] NS indicates no samples collected.

The data obtained on gross beta activity in Minnesota surface waters show a variation of concentrations, with no readily apparent trends. Differences in precipitation and flow rates of streams could contribute to this variation. Monthly averages of gross beta radioactivity in Minnesota raw surface waters ranged from 7 to 64 pCi/liter, which is well below the Public Health Service Drinking Water Standard of 1000 pCi/liter (*1*). Treated water in most cases contained less beta activity than the corresponding raw water.

REFERENCE

(*1*) PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962. Public Health Service Publication No. 956, Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402 (March 1963). Price 30 cents.

Previous coverage in *Radiological Health Data:*

Period	*Issue*
October 1957–August 1959	*April 1960*
August 1959–April 1962	*August 1962*
April 1962–November 1962	*April 1963*
December 1962–June 1963	*November 1963*
July–December 1963	*June 1964*
January–June 1964	*January 1965*

Section IV—Other Data

MEASUREMENT OF IODINE-131 IN BOVINE THYROIDS

Kenneth H. Falter and *George Murray*[1]

The Division of Radiological Health, U.S. Public Health Service, in cooperation with the Meat Inspection Division, U.S. Department of Agriculture, has been collecting and analyzing bovine thyroids for iodine–131 in order to supplement existing environmental radiation surveillance data. The study was begun on a pilot basis in September 1962, and the program was operative from January 1963 to January 1964. The program is described in detail in a previous report (*1*), which also presented data from 760 samples collected and analyzed between January 20 and June 29, 1963.

Between June 30, 1963, and January 3, 1964, when this phase of the program was temporarily suspended, a total of 1445 thyroid specimens were collected and analyzed for iodine–131 activity. Of these, 875 were from cows that were lactating at the time of slaughter, and 570 were from nonlactating cows. The counties from which samples were received are indicated in figure 1. The counties in black are in milkshed areas; those lightly shaded lie outside milkshed areas. The number of samples collected, their classification in terms of lactation status, and identification as to whether they were from a milkshed or not, are shown in table 1.

Results

Of the 1445 samples collected and analyzed, only 30 individual samples had iodine–131 levels exceeding 3.5 picocuries per gram. The significance of this level will be discussed below. Three weekly averages exhibiting concentrations above 3.5 picocuries per gram were observed in this study. These weekly averages and the 30 individual sample values are listed in table 2. The weekly average is the arithmetic mean for the given number of thyroids from cows slaughtered that week. The two-sigma or 95 percent counting error (95 percent C.E.) is an indication of the inherent statistical variation associated with all measurements of radionuclide concentrations. The concentration $\pm$ 95 percent C.E. is the range within which the true concentration is expected to lie 95 percent of the time.

Prior to November 1963, samples were counted for 100 minutes on either a single-channel or dual-channel gamma spectrometer, using a scintillation well detector containing a three-inch diameter NaI(Tl) crystal (*1*). Beginning in November 1963, samples were screened for 10 minutes on the dual-channel analyzer. If the net count rate was less than 3.5 counts per minute (cpm), this activity was considered to be due to fluctuation in the background, and the specimen activity was taken as nondetectable.

Weekly averages for those milksheds providing a continuing supply of specimens are plotted in figures 2–5. The solid lines connect the data points for lactating cows, and the dotted lines connect the data points for nonlactating cows.

[1] Mr. Falter was Project Officer, Bovine Thyroid Study, Research Branch, and is currently with the Training Branch, Division of Radiological Health, Public Health Service, U.S. Department of Health, Education, and Welfare, Washington, D.C. Dr. Murray is Staff Officer for Procedures and Requirements, Consumer Marketing Service, Meat Inspection Division, U.S. Department of Agriculture, Washington, D.C.

Figure 1. Sample ction ar as in the bovine thyroid collection program

Discussion of data

During the second half of the study, it was found that a long-lived radionuclide was affecting the assay of iodine–131 in some of the specimens. Nine specimens exhibiting little radioactive decay were investigated more closely, and the contamination was identified as radium–226. This phenomenon will be discussed more fully in a forthcoming report (*2*). Van Middlesworth (*3*) has also reported this type of contamination in samples of cattle thyroid glands.

Interpretation of the data is complicated by the presence of this long-lived radionuclide. The amount of radium–226 found in the nine specimens, if mistakenly taken to be iodine–131, would correspond to 8 pCi ^{131}I/g thyroid. A pooled sample consisting of all thyroids previously analyzed for iodine–131 was ashed and analyzed for radium–226 and found to contain about one-fifth the activity of the nine samples previously mentioned. This amount of radium–226, if considered to be iodine–131, would correspond to approximately 3.5 pCi ^{131}I/g thyroid.

Based on these two figures, 8 and 3.5 pCi ^{131}I/g thyroid, the data may be interpreted as follows: levels above 8 pCi ^{131}I/g thyroid may be interpreted as due to some combination of iodine–131 and radium–226 which could be misinterpreted as iodine–131. However, the maximum contribution of radium–226 is 8 pCi/g. Values below 3.5 pCi ^{131}I/g thyroid can be considered, on the average, as radium–226 contamination alone. Values between 3.5 and 8 pCi ^{131}I/g thyroid are subject to question as to how much of this activity is actually iodine–131 and how much is the radium–226 contamination. Consequently, we have defined 8 pCi ^{131}I/g thyroid as the lower level of reliability and have presented all samples with activity above 3.5 pCi ^{131}I/g.

Based on a calculation (*4*) that milk levels (pCi ^{131}I/liter) are, on the average, about 8 percent of the thyroid levels (pCi ^{131}I/g), then the lower limit of reliability for thyroids is equivalent to about 0.6 pCi ^{131}I/liter of milk. Thus, even allowing for small amounts of radium contamination, bovine thyroids proved more sensitive than fluid milk (by greater than one order of magnitude) as an indicator of environmental intrusions of iodine–131.

Table 1. Distribution of origin of bovine thyroids

State	Milkshed	Condition of cow	
		Lactating	Nonlactating
Ala	Montgomery	104	104
	Nonmilkshed	36	43
Ark	Little Rock	13	
	Nonmilkshed	1	
Colo	Nonmilkshed		2
Fla	Tampa		1
	Nonmilkshed	1	
Ga	Atlanta	5	6
	Nonmilkshed	1	
Idaho	Idaho Falls	1	
	Nonmilkshed	1	2
Iowa	Des Moines	113	116
	Nonmilkshed	37	23
Kans	Nonmilkshed	1	
La	New Orleans	34	9
	Nonmilkshed	114	55
Miss	Jackson	43	16
	Nonmilkshed	16	6
Mo	Kansas City	92	66
	St. Louis	24	14
	Nonmilkshed		2
Mont	Nonmilkshed	3	
Nebr	Nonmilkshed	1	
Okla	Oklahoma City	119	44
	Nonmilkshed	72	21
S. Dak	Nonmilkshed		1
Tenn	Memphis	4	
	Nonmilkshed		8
Tex	Austin	4	1
	Dallas	16	1
	Nonmilkshed	12	5
Utah	Salt Lake City	3	15
	Nonmilkshed	3	9
Wash	Seattle	1	
Total		875	570

Table 2. Values above the lower limit of reliability

State	Milkshed	Week 1963	Condition of cows	Average pCi ^{131}I/g	95% C.E.[a]
Weekly averages					
Ala:	Montgomery	9/15	[b]Lactating (4)	3.7	2.2
		10/20	Lactating (4)	4.3	1.0
Iowa:	Des Moines	10/27	Nonlactating (2)	4.1	0.9
Individual values					
Ala:	Montgomery	8/4	Lactating	6.3	3.6
		8/11	Nonlactating	3.6	2.2
		8/18	Nonlactating	3.5	2.5
		9/1	Nonlactating	4.6	2.6
		9/15	Lactating	9.6	8.5
		9/22	Lactating	4.2	3.6
		9/22	Nonlactating	4.6	1.9
		10/20	Lactating	5.0	1.8
		10/20	Lactating	4.4	1.5
		10/20	Lactating	4.3	2.8
		10/20	Lactating	3.7	1.2
		10/20	Nonlactating	4.8	1.7
	Nonmilkshed	8/25	Lactating	3.6	2.0
Iowa:	Des Moines	7/21	Nonlactating	3.7	2.5
		9/1	Lactating	4.3	1.5
		9/15	Lactating	5.2	1.7
		10/13	Nonlactating	9.4	2.5
		10/13	Nonlactating	5.2	3.0
		10/20	Nonlactating	4.6	2.4
		10/20	Nonlactating	3.5	2.2
		10/27	Lactating	8.4	1.5
		10/27	Lactating	4.6	1.5
		10/27	Nonlactating	4.5	1.0
La:	New Orleans	9/29	Nonlactating	5.7	1.9
Miss:	Nonmilkshed	10/27	Lactating	3.7	0.9
Mo:	Kansas City	8/4	Nonlactating	6.6	1.7
		9/15	Lactating	4.3	1.4
		9/15	Nonlactating	4.4	1.6
Okla:	Oklahoma City	7/21	Lactating	3.9	1.4
Utah:	Salt Lake City	10/27	Nonlactating	4.6	1.4

[a] Two-sigma or 95 percent counting error.
[b] Figures in parentheses represent number of specimens.

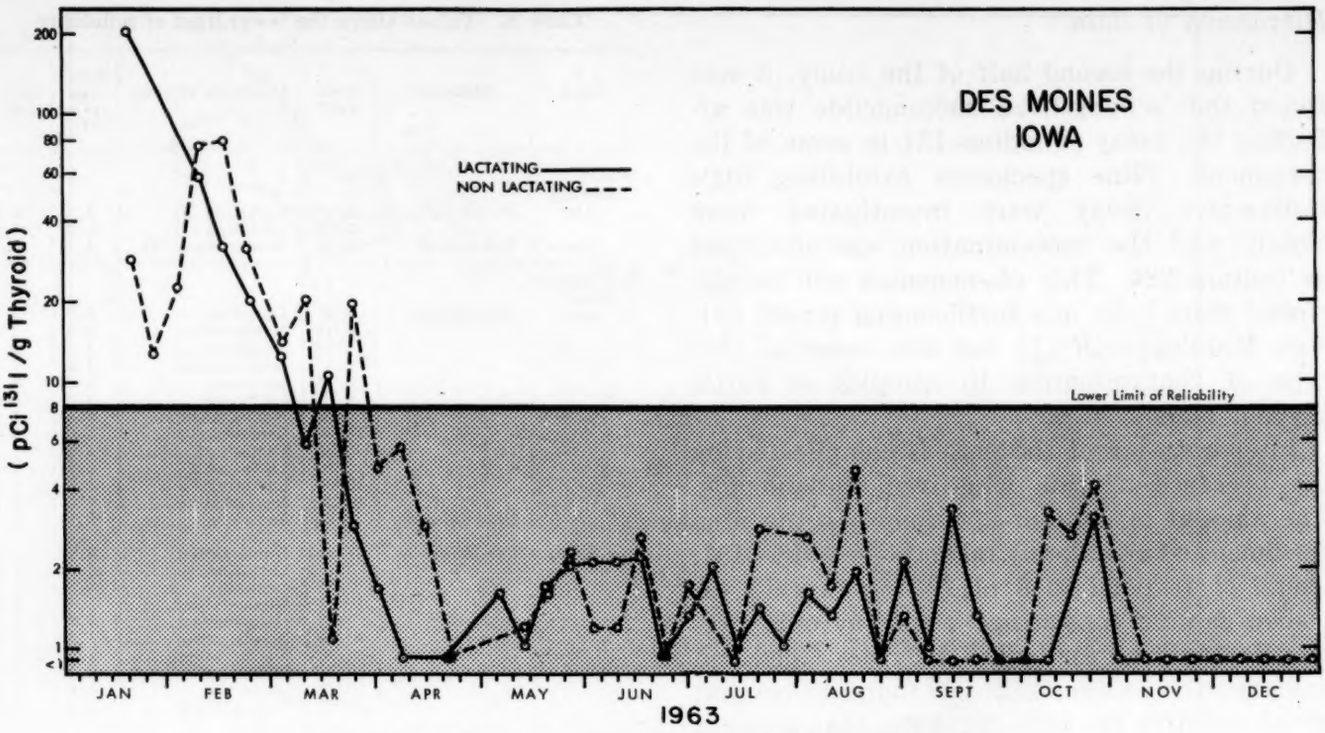

Figure 2. Weekly averages for Des Moines milkshed

Moreover, the use of a multichannel analyzer, or suitable method of gamma spectrum analysis using a single- or dual-channel analyzer, would readily identify any contribution of radium–226 to counts in the iodine–131 peak region. By this means, the lower level of reliability of the system could be reduced to about 1 to 2 pCi ^{131}I/g of thyroid.

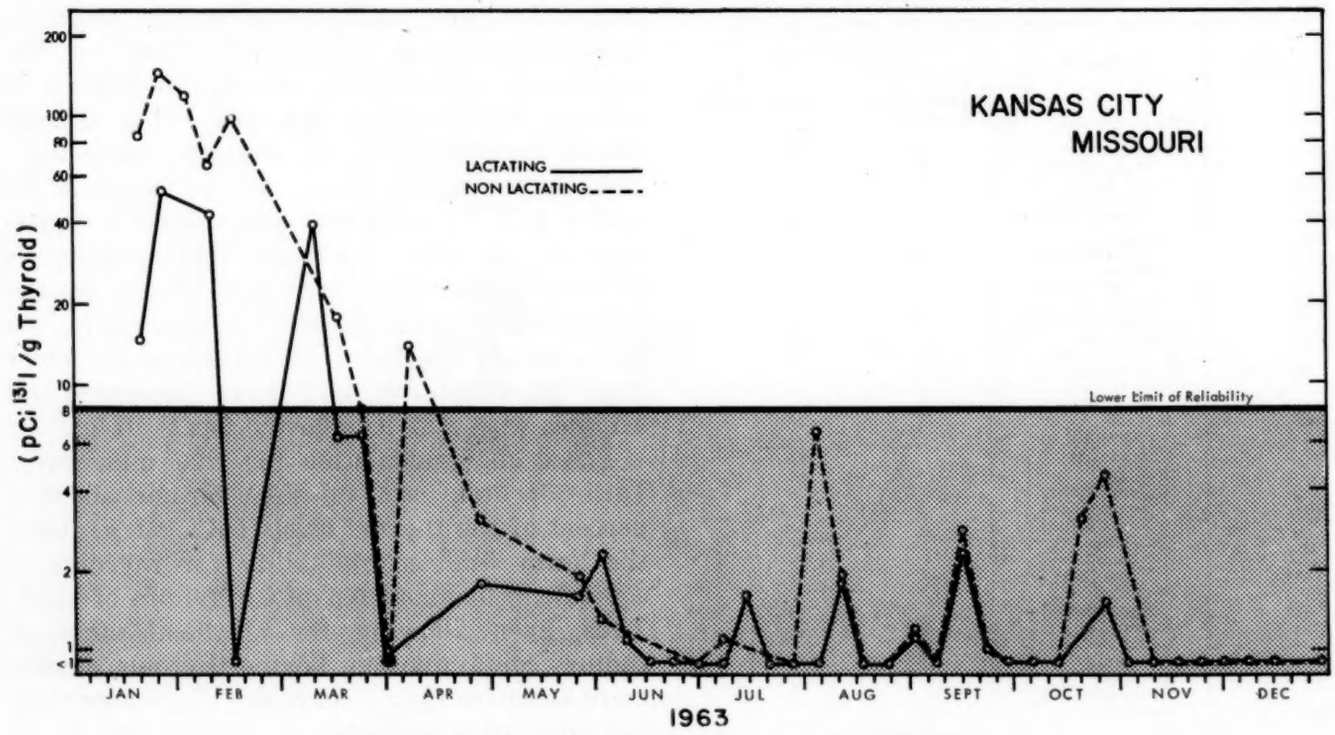

Figure 3. Weekly averages for Kansas City milkshed

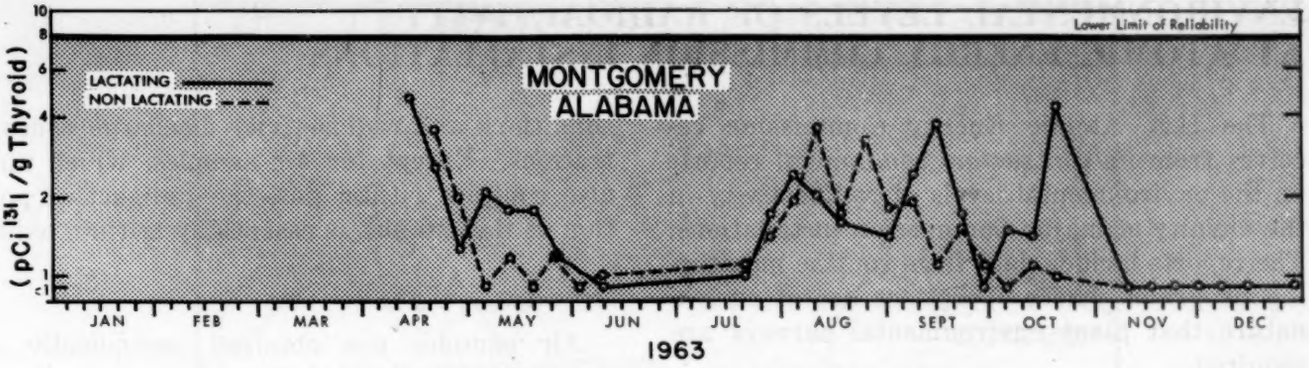

Figure 4. Weekly averages for Montgomery milkshed

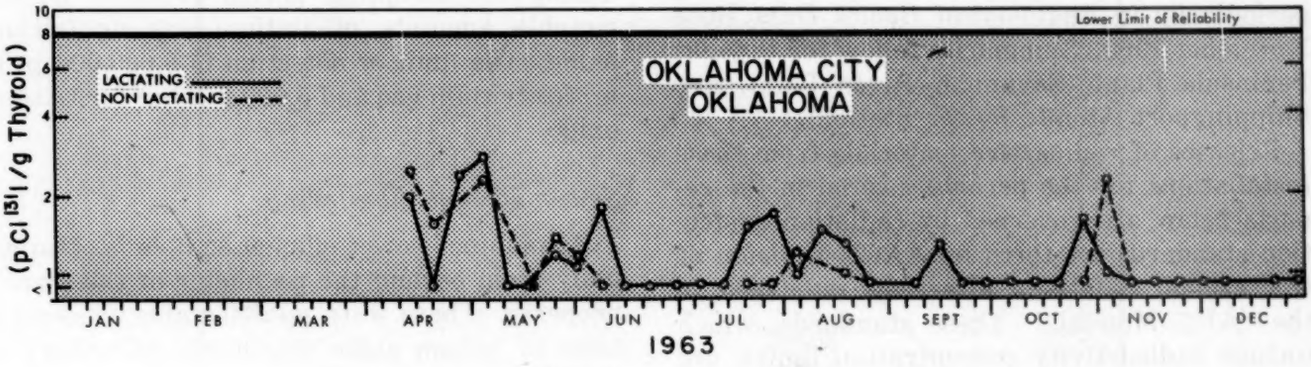

Figure 5. Weekly averages for Oklahoma City milkshed

Summary of study—
January 1963 to January 1964

Inasmuch as the collection of bovine thyroids was temporarily suspended in January 1964, the following section is presented to summarize the data obtained up to that time.

A total of 2205 thyroid specimens were collected and analyzed for iodine–131 from January 1963 to January 1964. These specimens have been categorized in table 3.

Milkshed averages ranged from a high of 202 pCi/g in the Des Moines milkshed in January 1963 down to the limit of reliability in April 1963.

Table 3. Summary of thyroid specimens

Specimen category	Milkshed	Nonmilkshed	Total
Lactating	872 (40%)	430 (19%)	1,302 (59%)
Nonlactating	623 (28%)	280 (13%)	903 (41%)
Total	1,495 (68%)	710 (32%)	2,205 (100%)

Conclusions

The problem of radium–226 contamination must be considered in any future bovine thyroid studies. The use of a suitable method of gamma spectrum analysis will identify any contribution of radium–226 to counts in the iodine–131 peak region. This will reduce the lower level of reliability of the system to 1 to 2 pCi ^{131}I/g thyriod. Bovine thyroids are more sensitive than fluid milk (by greater than one order of magnitude) as an indicator of environmental intrusions of iodine–131.

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(*1*) FALTER, K. H. *et al.* In vitro measurement of iodine–131 in bovine thyroids, Rad Health Data 4: 527–534 (October 1963).
(*2*) FALTER, K. H. Radium–226 in bovine thyroids (in preparation).
(*3*) VAN MIDDLESWORTH, L. Long-life radioactivity in occasional thyroids. Nature 203:199–200 (July 11, 1964).
(*4*) FISH, B. R. *et al.* The merits of cattle thyroid analysis for the detection of I–131 in the environment. App Health Phys Ann Report ORNL–3490: 72–73 (1962).

ENVIRONMENTAL LEVELS OF RADIOACTIVITY AT ATOMIC ENERGY COMMISSION INSTALLATIONS

The U.S. Atomic Energy Commission receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Summaries of the environmental radioactivity data for 22 AEC installations have appeared periodically in *Radiological Health Data* since November 1960. Summaries follow for Pinellas Peninsula Plant, Savannah River Plant, and Shippingport Atomic Power Station.

Releases of radioactive materials from these installations for the periods covered in the reports below are governed by radiation protection standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1] These standards, which include radioactivity concentration limits, are applicable to effluents released from AEC installations.

1. Pinellas Peninsula Plant[2] July–December, 1964

General Electric Company
St. Petersburg, Florida

Pinellas Peninsula Plant, shown in figure 1, is an electronic component production facility. The plant maintains an environmental monitoring program to measure the environmental levels of radioactive contamination associated with Plant effluents. These measurements serve as an index of the effectiveness of the Plant's contamination control measures. Environmental monitoring includes sampling of a single combined sewer effluent, milk from four local dairy farms, and air and surface water obtained at locations suggested by meteorological conditions and radioactivity discharge concentrations. Except for air samples, which may also contain tritium gas, the radioactive portion of the samples is essentially tritium oxide.

Air monitoring

Air samples are obtained periodically in areas up to 2 miles downwind from the exhaust stack. Analysis of the 28 samples collected during the sampling period revealed no detectable amounts of tritium gas or tritium oxide. The limit of detection is 9,600,000 pCi/m^3 for tritium gas and 5,000 pCi/m^3 for tritium oxide.

Sewer effluent monitoring

A combined sewer effluent sample is obtained daily from beyond the perimeter of the plant's property. There were no detectable concentrations of tritum oxide ($>$ 90,000 pCi/liter) in the 127 samples analyzed during the sampling period.[3]

Surface water sampling

Surface water samples are collected at monthly intervals at selected locations within 8 miles of the plant. The sampling areas are determined by interrelating the concentrations of radioactivity in exhaust stack effluent with meteorological data. There were no indications of tritium oxide ($>$ 90,000 pCi/liter) in the 49 surface water samples analyzed during the sampling period.

Milk sampling results

Sixteen samples of raw milk were collected from farms within a 3-mile radius of the Plant. These samples were analyzed by the Florida State Board of Health during 1964. No detectable concentrations ($>$ 90,000 pCi/liter) of tritium oxide were evident.

Previous coverage in *Radiological Health Data:*

Period	*Issue*
1960–1961	*July 1962*
Calendar year 1962	*June 1963*
Calendar year 1963	*September 1964*
January–June 1964	*February 1965*

[1] Part 20, "Standards for Protection Against Radiation," AEC Rules and Regulations, contains essentially the standards published in the "AEC Manual." The AEC Rules and Regulations are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, on a subscription basis at $3.50 for 3 years.

[2] Summarized from "Environmental Monitoring, July 1 through December 31, 1964," General Electric Company, Pinellas Peninsula Plant, St. Petersburg, Fla.

[3] Expressions in parentheses indicate limits of detectability in the respective environmental samples.

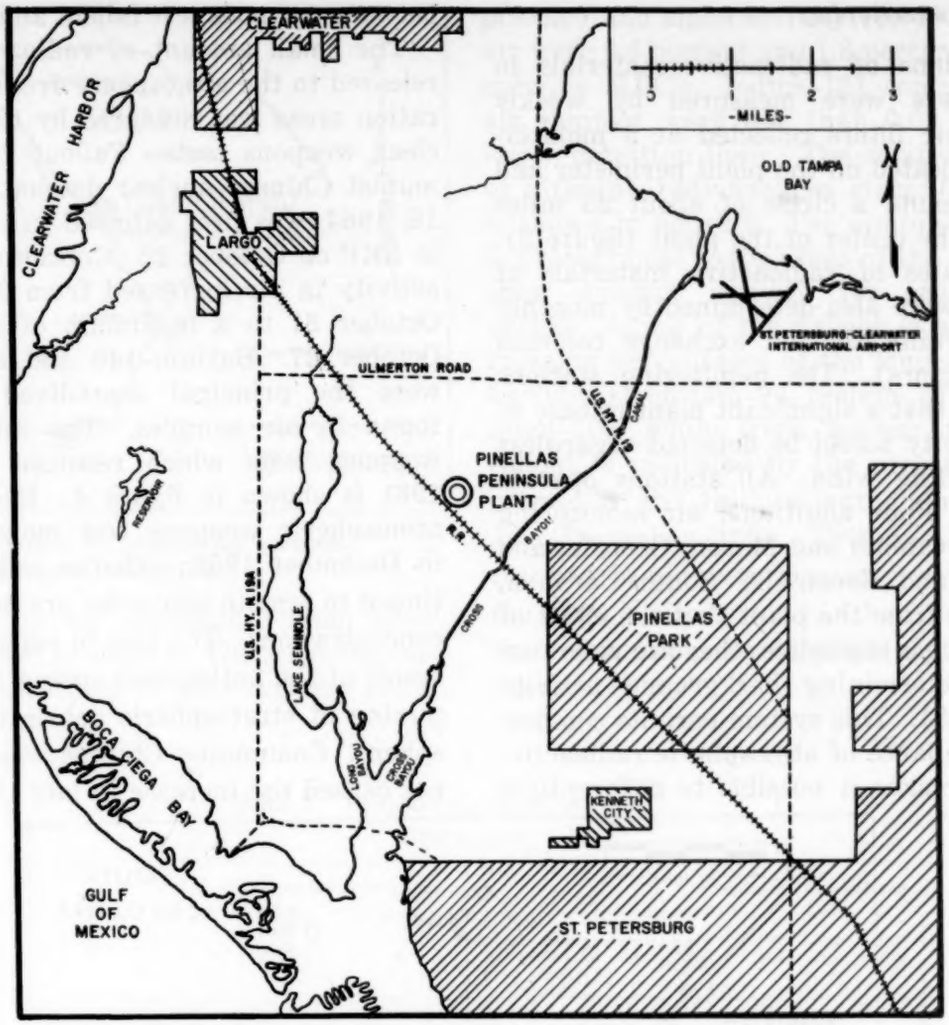

Figure 1. Location of the Pinellas Peninsula Plant

2. Savannah River Plant July–December 1964[4]

E. I. du Pont de Nemours
Aiken, South Carolina

The Savannah River Plant (SRP), built and operated for the Atomic Energy Commission by E. I. du Pont de Nemours and Company, occupies an area of 312 square miles along the Savannah River, 22 miles downstream from Augusta, Georgia. Production facilities include a fuel preparation area, four reactors, two fuel separation areas, and a heavy water production plant. A basic goal in plant operation is total containment of radioactive waste. Although some very low level gaseous and liquid wastes are discharged to the environment in controlled releases, dispersal is adequate to insure environmental concentrations below recommended guides.

The du Pont Health Physics Section has maintained a continuous monitoring program since 1951 (prior to plant startup) to determine the concentrations of radioactive materials in a 1200-square mile area outside the plant. This surveillance determines the magnitude and character of any radioactivity above natural levels. Measured concentrations of radionuclides in air, water, and milk are compared with the Maximum Permissible Concentrations (MPC) in the AEC Manual (see footnote 1).

Sensitive instruments, which can detect traces of radioactive materials far below concentrations of hazard significance, are used to determine radioactivity in the environs. Maximum and minimum values given are for individual samples collected during the reporting period.

[4] Summarized from "Effect of the Savannah River Plant on Environmental Radioactivity, Semiannual Report, July through December 1964." (DPSPU 65–30–1).

Atmospheric monitoring

Concentrations of radioactive materials in the atmosphere were measured by weekly analyses of air filters collected at 5 monitoring stations located on the plant perimeter and 9 stations around a circle of about 25 miles radius from the center of the plant (figure 2). Deposition rates of radioactive materials at each station were also determined by monthly analyses of rainwater ion exchange columns (fallout collectors). The monitoring stations are spaced so that a significant plant release of airborne activity would be detected regardless of the prevailing wind. All stations operate continuously. Four additional air monitoring stations at Savannah and Macon, Georgia, and at Columbia and Greenville, South Carolina, are so distant from the plant that the effect of SRP operations is negligible; they are reference points for determining background activity levels (figure 3). This system permits comprehensive surveillance of atmospheric radioactivity and also makes it possible to differentiate between weapons test fallout and plant releases.

The small amount of radioactive materials released to the atmosphere from the fuel separation areas was obscured by fallout from nuclear weapons tests. Fallout from the Communist Chinese nuclear detonation of October 16, 1964, was first detected in the atmosphere at SRP on October 22. Concentrations of beta activity in air increased from 0.09 pCi/m³ on October 21 to a maximum of 2.4 pCi/m³ on October 27. Barium–140 and lanthanum–140 were the principal short-lived radionuclides found in air samples. The influence of the weapons tests which resumed in September 1961 is shown in figure 4. Even though the atmospheric weapons test moratorium began in December 1962, airborne radioactivity continued to remain above the pre-September 1961 concentrations. The rise in early 1964 was the result of the anticipated spring increase in the mixing of stratospheric debris into the troposphere. Communist Chinese weapons test fallout caused the increase in late 1964.

Figure 2. Environmental sampling locations, Savannah River Plant

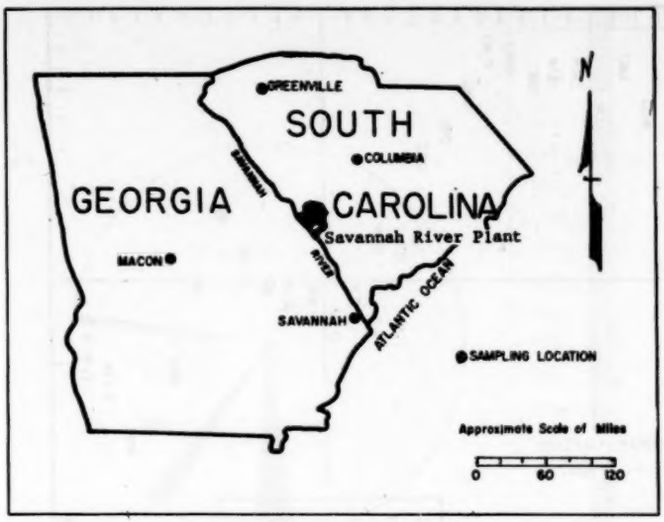

Figure 3. Distant air monitoring stations, Savannah River Plant

Radioactivity in air, determined from filter analyses, is shown in table 1. The July–December 1964 concentrations of beta activity (0.35 pCi/m³) and alpha activity (0.0007 pCi/m³) in air were 0.4 percent and 1.8 percent of their respective MPC's. Iodine–131 concentrations in air samples were less than 0.02 pCi/m³, the lower detection limit. The relative abundance of airborne radionuclides since January 1963 is shown in figure 5. The diminishing activity is proportional to the areas of the circles which show average activity for each six-month period. Aging of the fallout is seen from increasing percentages of the longer-lived radionuclides strontium–90, cesium–137, and ruthenium–106, while fresh nuclear weapons test fallout is indicated by the presence of ruthenium–103 and barium–lanthanum–140 during July–December 1964. Tritium oxide concentrations in air were measured continuously at the plant perimeter and at the 25-mile stations; the average concentration did not exceed 2 percent of the MPC.

Table 1. Radioactivity in air, pCi/m³

(Filter analyses)

	Plant-perimeter locations						25-mile-radius locations									
	A	B	C	D	E	Av	Aiken Airport	Aiken State Park	Allendale	Barnwell	Bush Field	Langley	Sardis	Waynesboro	Williston	Av
Alpha Emitters in Air [a] (multiply by 10^{-3})																
Max	2.4	1.8	1.0	1.6	1.2		1.3	1.6	1.2	2.0	2.0	2.1	1.3	1.2	4.9	
Min	[b]	0.3														
Av	0.6	0.7	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.7	0.8	0.7	0.6	0.9	0.7
Nonvolatile Beta Emitters in Air, [c]																
Max	1.71	1.40	1.34	1.73	1.73		1.70	1.20	2.03	1.49	1.12	1.04	1.46	1.66	1.34	
Min	0.07	0.05	0.09	0.07	0.07		0.07	0.08	0.08	0.09	0.06	0.08	0.09	0.01	0.06	
Av	0.38	0.35	0.36	0.39	0.36	0.36	0.42	0.34	0.38	0.36	0.28	0.35	0.35	0.34	0.34	0.35
Specific Radionuclides in Air (Averages),																
^{137}Cs	0.02	0.03	0.02	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
^{144}Ce	.14	.13	.12	.12	.12	.13	.13	.13	.12	.13	.12	.10	.12	.10	.13	.12
^{106}Ru	.04	.03	.04	.03	.04	.04	.04	.03	.03	.03	.04	.02	.04	.02	.04	.03
^{103}Ru	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
^{95}Zr-Nb	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
^{54}Mn	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
^{140}Ba-La	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07

	Distant air-monitoring locations									
	Columbia, S.C.	Greenville, S.C.	Macon, Ga.	Savannah, Ga.	Av		Columbia, S.C.	Greenville, S.C.	Macon, Ga.	Savannah, Ga.	Av
Alpha Emitters in Air [a] (multiply 10^{-3})						Nonvolatile Beta Emitters in Air [c]					
Max	2.5	2.8	2.2	1.4			1.14	1.26	1.36	1.22	
Min							0.06	0.08	0.08	0.11	
Av	0.8	1.0	0.8	0.7	0.8		0.33	0.36	0.34	0.34	0.34
Specific Radionuclides in Air (Averages),											
^{137}Cs	0.03	0.03	0.02	0.03							
^{144}Ce	.12	.15	.12	.18							
^{106}Ru	.02	.05	.03	.09							
^{103}Ru	.01	.01	.01	.01							
^{95}Zr-Nb	.02	.02	.02	.02							
^{54}Mn	.01	.01	.01	.01							
^{140}Ba-La	0.07	0.07	0.07	0.07							

[a] MPC = 40; Sensitivity of analysis 0.3.
[b] Blank indicates levels below sensitivity of analysis.
[c] MPC = 100; sensitivity of analysis, 0.006.

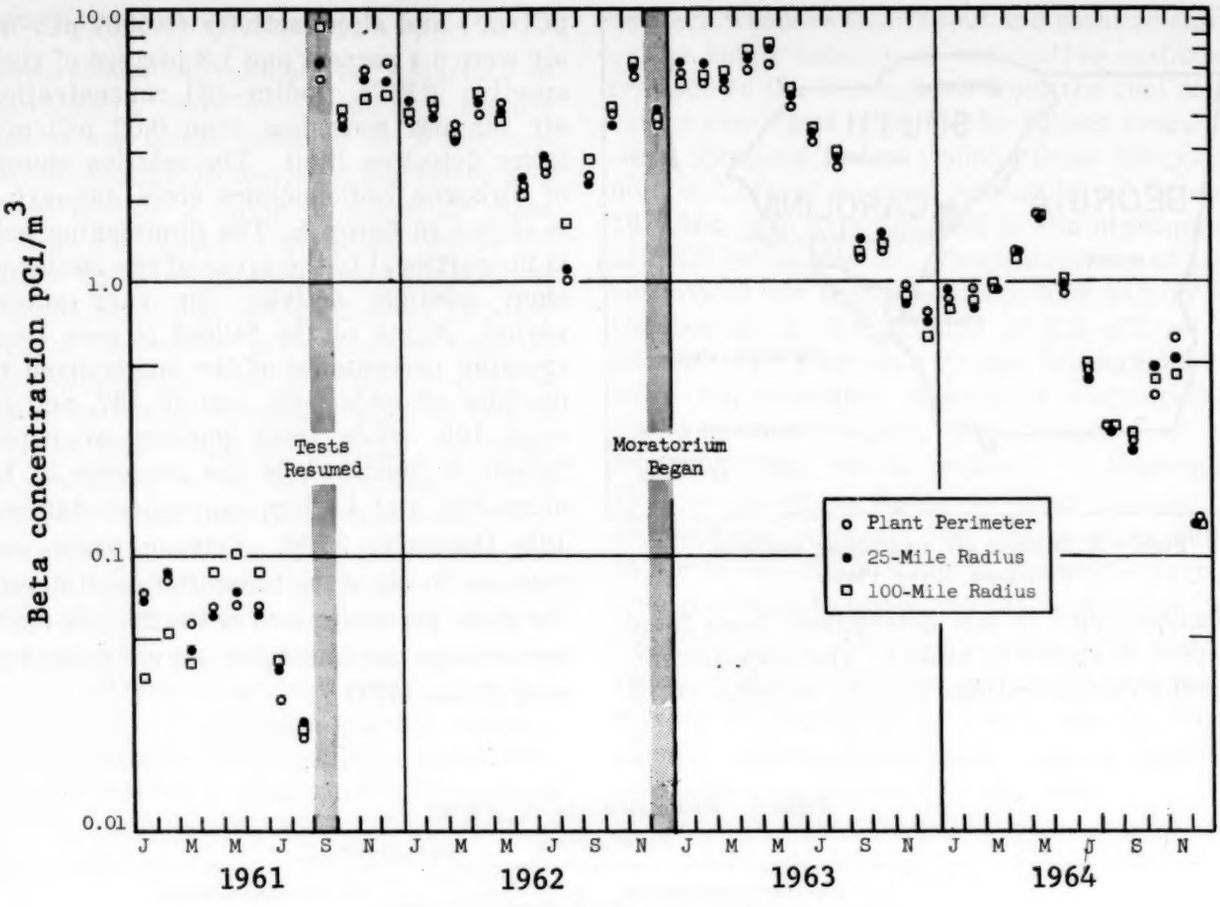

Figure 4. Effects of weapons tests

Deposition of radioactive materials during the second half of 1964 totaled 69 mCi/sq mile at plant perimeter locations and 65 mCi/sq mile at the 25-mile radius locations; comparable values for the first half of 1964 were 366 mCi/sq mile and 343 mCi/sq mile, respectively. Deposition at each sampling location is recorded in table 2.

Vegetation

Radioactive contamination of vegetation may result from direct deposition on exposed surfaces or absorption of radioactivity from the soil. Bermuda grass was selected for analysis because of its importance as a pasture grass for dairy herds and its availability during all seasons of the year.

Table 2. Total fallout deposited, second half of 1964

(mCi/sq mi)

Radionuclide	Plant perimeter locations						25-mile-radius locations									
	A	B	C	D	E	Av	Aiken Airport	Aiken State Park	Allendale	Barnwell	Bush Field	Langley	Sardis	Waynesboro	Williston	Av
Alpha [a]	4.9	8.9	6.0	9.5	7.2	7.3	9.1	4.2	7.3	1.4	9.1	6.8	8.7	7.4	5.8	6.6
^{90}Sr	3	3	5	5	4	4	5	3	5	2	5	5	6	4	4	4
^{137}Cs	11	9	10	13	12	11	11	10	11	3	9	11	10	8	13	10
^{144}Ce	15	32	27	37	38	30	22	19	27	11	30	24	29	23	38	25
^{106}Ru	3	4	6	6	6	5	5	4	5	1	6	5	3	2	4	4
^{103}Ru	9	11	13	16	16	13	16	10	14	9	13	12	18	14	18	14
^{95}Zr-Nb	2	2	2	2	3	2	3	2	3	1	3	3	3	2	6	3
^{54}Mn	3	3	4	5	5	4	5	4	5	2	5	5	4	3	10	5

[a] Multiply by 10^{-2}.

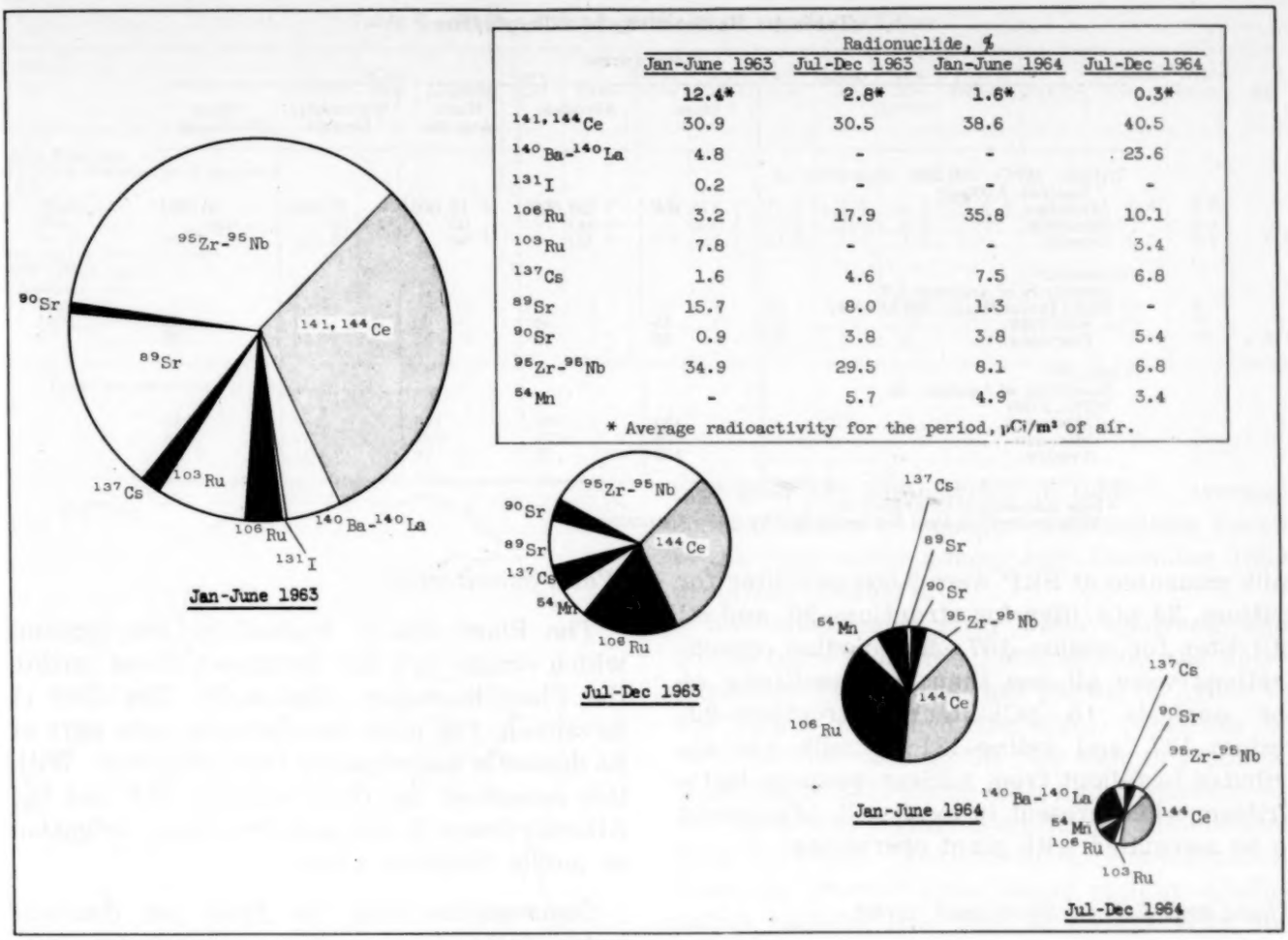

Figure 5. Relative abundance of airborne radionuclide activity (weapons test fallout)

Grass samples were collected at 7 locations along the plant perimeter and at 7 other locations along a 25-mile radius route. (These are not designated on figure 2.) Samples from each quadrant of the plant and of the surrounding area were composited for weekly analysis. Radionuclides in grass samples were from weapons test fallout. Alpha emitters averaged 0.1 pCi/gram at plant perimeter and 25-mile radius locations; gamma emitters averaged 56 pCi/gram and 37 pCi/gram, respectively. Radionuclide concentrations comprising gamma activity are presented in table 3.

Milk

Milk was sampled at 4 dairies within a 25-mile radius of the plant, as shown in figure 2. Samples were taken weekly and analyzed for tritium, iodine–131, and cesium–137. Strontium–90 determinations were made quarterly. Milk produced in the area and sold by major distributors was also analyzed for these radionuclides. Results from analyzing milk for radioactivity during July–December 1964 are given in table 4.

Average concentrations of radionuclides in

Table 3. Radioactivity on vegetation, pCi/g

	Alpha	^{137}Cs	^{144}Ce	^{106}Ru	^{95}Zr-Nb	^{54}Mn
Sensitivity of analysis	0.10	0.07	0.32	0.45	0.06	0.05
Plant perimeter (7 locations)						
Maximum	0.52	16	139	11	4	10
Average	.11	6	42	4	1	3
25-Mile radius (7 locations)						
Maximum	0.64	4	65	8	2	4
Average	.14	3	23	7	<1	3

Table 4. Radioactivity in milk, pCi/liter

(Local dairies)

	Aiken	Allendale	North Augusta	Waynesboro, Georgia	Major Distributors [b]
Tritium MPC: 300,000; Sensitivity of Analysis: 3,000					
Maximum	10,000	20,000	12,000	15,000	21,000
Minimum	(a)	(a)	(a)	(a)	(a)
Average	(a)	(a)	(a)	3,000	3,000
Strontium^{90}					
Sensitivity of Analysis: 1.0					
Daily Intake Guide: 200 pCi/day					
Sept 1964	36	44	40	42	38
Dec 1964	26	22	33	26	29
Cesium^{137}					
Sensitivity of Analysis: 25					
MPC: 2,000					
Maximum	160	165	140	138	131
Minimum	78	<32	<32	<32	56
Average	109	73	78	61	88

[a] Less than sensitivity of analysis.
[b] Milk produced in local dairies but sold by major distributors.

milk measured at SRP were 3,000 pCi/liter for tritium, 34 pCi/liter for strontium–90, and 82 pCi/liter for cesium–137. Radioiodine concentrations were all less than the sensitivity of the analysis (5 pCi/liter). Strontium–90, cesium–137, and iodine–131 in milk are attributed to fallout from nuclear weapons tests. Tritium when present in local milk is assumed to be associated with plant operations.

Algae and fish in Savannah river

Fish (predominantly bream) and indigenous algae, primarily green (*Vaucheria*) and blue-green (*Phormidium*), were collected weekly upstream, adjacent to, and downstream from the Plant. Determination of radionuclides in algae is important because algae concentrate certain radionuclides and form a part of the food chain of aquatic organisms. Data from analysis of fish and algae samples are given in table 5. Beta concentrations in algae adjacent to and downstream from the plant indicate some plant contribution; however, the slight increase is of no biological significance.

Water monitoring

The Plant site is drained by five streams which empty into the Savannah River within the Plant boundary (figure 6). The City of Savannah, 130 miles downstream, gets part of its domestic water supply from the river. With this exception, the river between SRP and the Atlantic Ocean is not used for either irrigation or public drinking water.

Communities near the Plant get domestic water from deep wells or surface streams. Public water supplies from 14 surrounding towns were collected and analyzed monthly; concentrations of alpha activity (1.6 pCi/liter) and beta activity (6.4 pCi/liter) were essentially the same as those observed before plant startup in 1951. Data from analyses of all public water samples are given in table 6.

River water, analyzed weekly, was sampled continuously at 4 locations (upstream, adjacent to, and as far as 10 miles downstream) as shown in figure 2. Concentrations of alpha and nonvolatile beta emitters in river water for the

Table 5. Radioactivity in Savannah River aquatic specimens, pCi/g

Location	Algae (dry weight)				Fish (wet weight)						
	Samples	Max	Min	Av	Samples	Bone			Flesh		
						Max	Min	Av	Max	Min	Av
Nonvolatile Beta Emitters											
Sensitivity of Analysis: Varied due to differing sample size											
Control (3 miles upstream from Plant)	21	150	45	60	30	60	1	19	9	1	3
Along Plant boundary	18	380	40	100	31	1,100	1	57	20	1	5
Highway 301 crossing (10 miles downstream from Plant)	18	170	50	85	44	120	1	29	36	1	5

Table 6. Radioactivity in public water supplies, pCi/liter

	Aiken	Allendale	Augusta	Barnwell	Bath	Blackville	Clearwater	Jackson	Langley	New Ellenton	North Augusta	Sardis	Waynesboro	Williston	Av
Alpha Emitters															
MPC: 10; Sensitivity of Analysis: 0.2															
Max	2.2	0.3	1.8	0.2	5.0	0.6	2.7	16.0	2.4	2.1	0.4	0.3	0.6	2.0	
Min	0.9	(a)	(a)	(a)	2.0	(a)	0.4	6.6	1.0	0.8	(a)	(a)	(a)	0.4	
Av	1.6	(a)	0.4	(a)	2.8	0.2	1.1	11.0	1.6	1.5	(a)	(a)	0.3	0.9	1.6
Nonvolatile Beta Emitters															
MPC: 3000; Sensitivity of Analysis: 4.0															
Max	6	(a)	10	(a)	9	(a)	7	40	7	10	18	(a)	(a)	4	
Min	(a)	(a)	(a)	(a)	5	(a)	(a)	20	(a)	(a)	(a)	(a)	(a)	(a)	
Av	(a)	(a)	5	(a)	7	(a)	4	28	5	6	7	(a)	(a)	(a)	6.4

[a] Less than sensitivity of analysis.

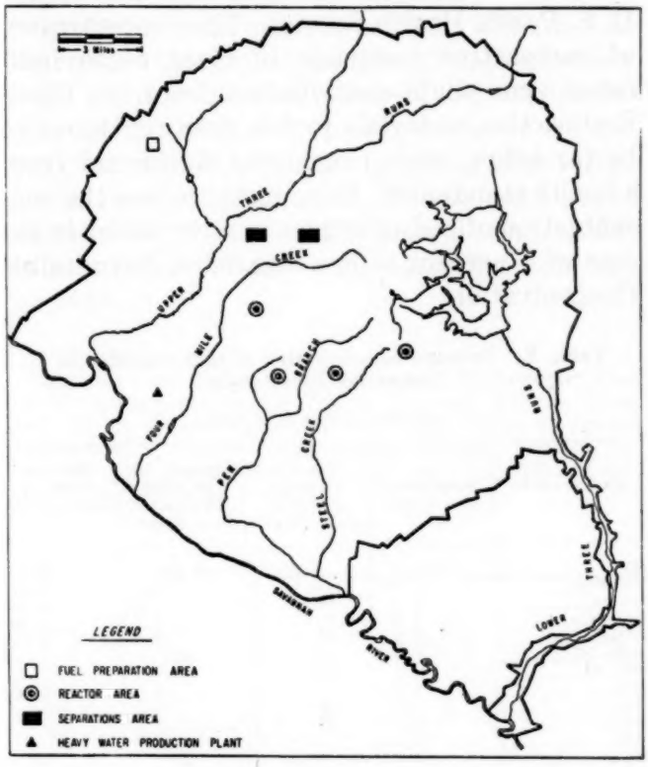

Figure 6. SRP production areas and effluent streams

past year are summarized in table 7; average concentrations of specific radionuclides found in the river water during July–December 1964 are given in table 8.

Radionuclides in river water upstream and downstream from the Plant during the July–December 1964 period are shown in figure 7; the values represent the total quantities of radionuclides passing the two sampling points. Neptunium–239, iodine–131, and chromium–51 are the primary gamma-emitting radionuclides from the Plant. These nuclides, released mainly from the reactor areas, decay rapidly (radioactive half-life less than 30 days). With the exception of strontium–89, most longer lived materials in river water came from nuclear weapons tests. The maximum weekly strontium–89 concentration in river water downstream from the Plant was 5 pCi/liter. Tritium (^3H), a beta emitter and the most abundant radionuclide released to the river, is produced by neutron irradiation of heavy water moderator in reactors. Chromium–51, the second most abundant radionuclide released to the river, is

Table 7. Radioactivity in Savannah River water, pCi/liter

Period data	Control (3 miles upsteam from plant)	Plant perimeter		Highway 301 (10 miles downstream from plant)
		1	2	
Alpha Emitters				
MPC: 10; Sensitivity of Analysis: 0.2				
July-Dec 1964: Max	1.0	0.6	0.4	0.5
Min	(a)	(a)	(a)	(a)
Av	0.3	0.2	(a)	(a)
Jan-June 1964: Av	0.3	(a)	(a)	(a)
Nonvolatile Beta Emitters				
MCP: 3000; Sensitivity of Analysis: 4.0				
July-Dec 1964: Max	25	38	29	31
Min	(a)	6	8	7
Av	10	15	14	14
Jan-June 1964: Av	12	20	21	21

[a] Less than sensitivity of analysis.

produced by neutron irradiation of stable chromium (a component of the stainless steel used in reactor parts). Tritium and chromium–51 are among the least dangerous of all radionuclides because neither concentrates in body tissues; their concentrations in river water were 4 percent and 0.003 percent of their respective MPC's. Average concentrations of all radionuclides found in river water during July–December 1964, as shown in table 8, were only small fractions of the permissible concentrations.

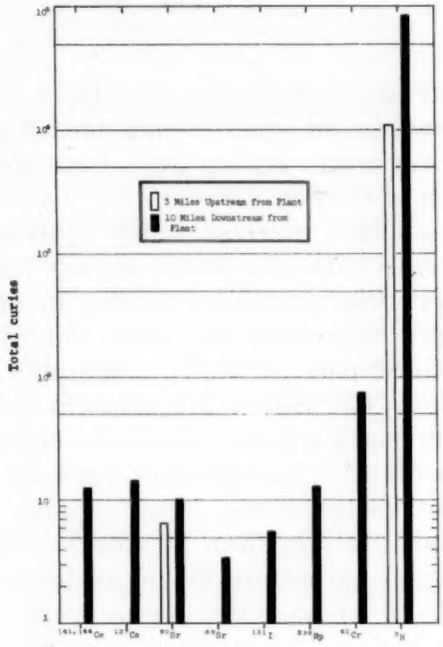

Figure 7. Radionuclides in river water during July–December 1964. (Only ^{90}Sr and ^{3}H were detectable upstream.)

Environmental gamma radiation levels

Monthly measurements of environmental gamma radiation were made with portable Geiger-Mueller survey instruments. January–June 1964 data in table 9 are characteristic of individual station observations during the past several years; the readings are not precise but are sufficiently accurate to illustrate any significant variations above background. The differences among the values shown are within the variance anticipated due to differences in normal background and in instrument response characteristics.

The quantity of radioactive waste released by the Savannah River Plant to its environs was, for the most part, too small to be distinguished from natural background radiation, or was obscured by worldwide fallout from nuclear weapons testing during past years. Beta activity in air, which shows no relationship to plant operations, was about one-eighth of that for the same period of 1963. Radionuclides in milk were at the same levels as those reported for most sections of the United States by the U. S. Public Health Service. The concentration of radioactive materials in river algae indicated some slight contribution from the Plant. Radioactive materials in fish flesh continued to be far below levels considered significant from a health standpoint. In no instance was the concentration of radionuclides in river water in excess of 4 percent of the Maximum Permissible Concentration.

Table 8. Average concentration of radionuclides in Savannah River water

(Concentration, pCi/liter)

Radionuclide	Sensitivity of Analysis	Control (3 miles upstream from Plant)	Highway 301 (10 miles downstream from Plant)	Percent MPC at Highway 301
^{3}H	600	1,600	12,000	4.0
$^{103, 106}Ru$	3.2	(a)	3.5	0.11
$^{141, 144}Ce$	2.5	(a)	5.0	0.16
$^{134, 137}Cs$	0.6	(a)	3.2	0.16
^{239}Np	0.9	(a)	3.0	0.01
^{140}Ba-La	1.6	(a)	(a)	—
^{95}Zr-Nb	0.5	(a)	(a)	—
^{51}Cr	4.3	(a)	18.0	0.003
^{89}Sr	0.3	(a)	0.4	(a)
^{131}I	0.5	(a)	1.5	(a)
^{90}Sr	0.01	1.1	1.7	(a)
^{60}Co	1.4	(a)	(a)	—
^{65}Zn	1.1	(a)	1.2	0.01
^{54}Mn	0.4	(a)	(a)	—

[a] Less than sensitivity of analysis.

Previous coverage in *Radiological Health Data:*

Period	*Issue*
July–December 1961	*September 1962*
Calendar Year 1962	*August 1963*
Calendar Year 1963	*August 1964*
January–June 1964	*February 1965*

Table 9. Environmental gamma radiation

(mR/24 hours)

	Plant perimeter locations						25-mile-radius locations									
	A	B	C	D	E	Av	Aiken Airport	Aiken State Park	Allendale	Barnwell	Bush Field	Langley	Sardis	Waynesboro	Williston	Av
Max	0.40	0.38	0.38	0.41	0.38		0.37	0.41	0.42	0.43	0.43	0.38	0.37	0.33	0.45	
Min	0.30	0.29	0.27	0.26	0.25		0.33	0.24	0.26	0.28	0.35	0.34	0.31	0.30	0.29	
Av	0.36	0.33	0.33	0.36	0.33	0.34	0.35	0.32	0.33	0.36	0.39	0.36	0.34	0.32	0.38	0.34

3. Shippingport Atomic Power Station[5] Calendar year 1964

Duquesne Light Company
Shippingport, Pennsylvania

Environmental radiation monitoring at the Shippingport Atomic Power Station began with a two-year preoperational survey program to establish background levels at the site of the world's first large-scale nuclear-powered electric generating station. Following initial operation of the Plant in December 1957, this program was continued as originally conceived through the third quarter of 1961, when it was determined that fewer sampling locations closer to the Plant would provide equal or better evaluation of the effects of plant operation on the environment. The present program of environmental monitoring consists of measurements of radioactivity in air, fallout, and Ohio River water. Figure 8 shows the sampling locations for 1964.

[5] Summarized from "Environmental Radioactivity at the Shippingport Atomic Power Stations for the First Half of 1964" (PNRO–DEV–B1) and "Environmental Radioactivity at the Shippingport Atomic Power Station for the Second Half of 1964 and Calendar Year, 1964". (PNRO–DEV–133).

Release of radioactive materials, January–June 1964

During the first six months of 1964, a total of 0.403 Ci of liquid radioactive waste (exclusive of tritium), 0.887 Ci of tritium and 2.4 Ci of xenon–133 gas were released into the environment at concentrations less than those given in the AEC Manual (see footnote 1, p. 456). The six-month average concentration of gross radioactivity in the liquid effluent was 9.3 pCi/liter, and that for tritium was 20 pCi/liter. Xenon–133 was released at a concentration no greater than 3,400 pCi/m³ air.

An incinerator for burning contaminated combustible material is located in the waste disposal building. The exhaust from the incinerator passes through a wet scrubber and a filter before entering the stack. The average gross radioactivity of incinerator effluent ranged from 3.8 to 11.0 pCi/m³. These concentrations did not exceed the MPC for unidentified radioactivity (100 pCi/m³).

Release of radioactive materials, July–December 1964

During the second six months of 1964 a total of 0.130 Ci of liquid radioactive waste (exclusive of tritium), 0.505 Ci of tritium, and 0.312

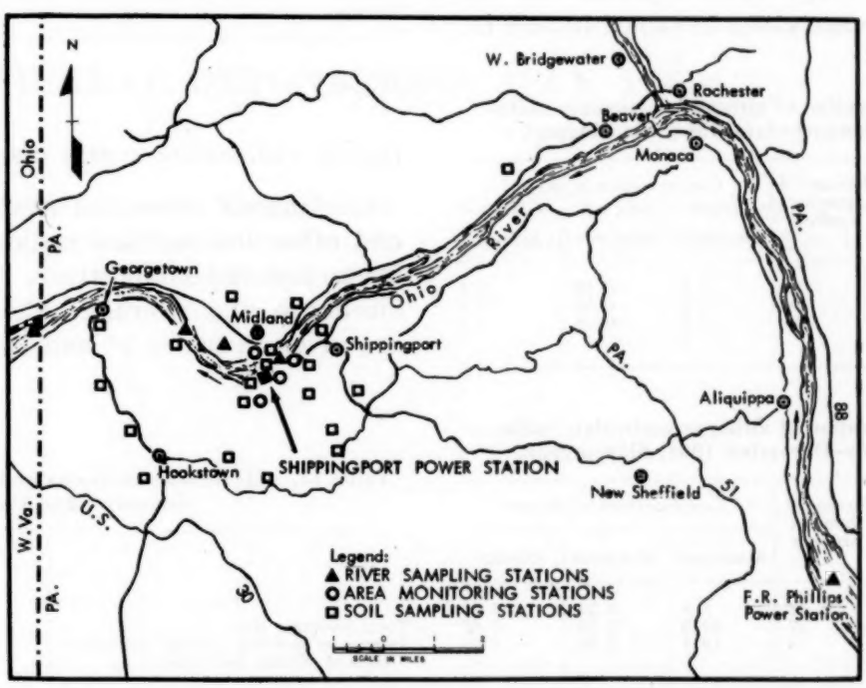

Figure 8. Shippingport Power Station, sampling locations

mCi of airborne radioactivity were released into the environment at concentrations less than those recommended by State and Federal regulations. The six-month average concentration of gross radioactivity in the liquid effluent was 5.83 pCi/liter and that for tritium was 22.6 pCi/liter. The airborne radioactivity was released at air concentration no greater than 100 pCi/m³.

During the second half of 1964, no radioactive gas was released to the atmosphere. However, small amounts of airborne particulate radioactivity were released from incinerator operations and the exhausts of several ventilation systems. The incinerator operated only during the months of July and August, releasing an estimated radioactivity of 0.044 mCi at a maximum concentration of 9.8 pCi/m³. This concentration is well within the MPC for unidentified radioactivity (100 pCi/m³).

Air monitoring

Airborne particulates are sampled at three area monitoring stations by means of a continuously moving paper tape sampler with an end-window Geiger-Mueller detector and recorder. A one-half hour decay time is allowed before counting, hence, naturally occurring radon and thoron daughters would be present. Maximum, minimum and average concentrations for the six month periods are given in tables 10 and 11.

Table 10. Concentration of airborne particulate radioactivity during January–June 1964, Shippingport

Station number	Percent of time not working	Concentration in pCi/m³		
		Maximum	Minimum	Average
1	42	7.8	0.08	1.4
2	38	7.9	0.08	1.7
3	38	6.9	0.08	1.2
(MPC = 100pCi/m³)				

Table 11. Concentration of airborne particulate radioactivity during July–December 1964, Shippingport

Station number	Percent of time not working	Concentration in pCi/m³		
		Maximum	Minimum	Average
1	54	7.8	0.24	2.30
2	27	62.8	0.24	5.66
3	4	10.4	0.08	2.46
(MPC = 100pCi/m³)				

Area monitoring stations 1, 2, and 3 are located as shown in figure 8.

Fallout sample

Monthly pot samples were collected at each of the three area monitoring stations (same locations as for air). Maximum, minimum, and average monthly deposition rates are given in tables 12 and 13.

Table 12. Gross beta in fallout, Shippingport average monthly deposition, January–June 1964

Station number	Deposition, nCi/m²		
	Maximum	Minimum	Average
1	211.5	35.5	92.6
2	137.4	28.6	83.0
3	197.2	38.6	96.1
Average			90.6

Table 13. Gross beta in fallout, Shippingport average monthly deposition, July–December 1964

Station number	Deposition, nCi/m²		
	Maximum	Minimum	Average
1	52.1	5.87	13.4
2	61.0	5.98	28.6
3	62.5	4.13	26.1
Average			22.7

Liquid radioactive waste disposal

Continuous controlled discharges of tritium and other unidentified radioactive wastes are made into the Ohio River. The quantities of discharge and average effluent concentration are given in tables 14 and 15.

Table 14. Liquid wastes discharged into the Ohio River, January–June 1964

	Tritium	Unidentified radioactivity
Total discharge (Ci)	0.877	0.403
Average of monthly average concentrations of effluent (pCi/liter)	20.0	9.3

Table 15. Liquid wastes discharged into the Ohio River, July–December 1964

	Tritium	Unidentified radioactivity
Total discharge (Ci)	0.505	0.130
Average of monthly average concentrations of effluent (pCi/liter)	22.6	5.83

Ohio River water monitoring

River water samples were collected by a continuous sampler upstream at the Shippingport condenser cooling water-intake and by grab sampling downstream at the condenser cooling-water outfall. (The downstream continuous sampler was not functioning.) These samples were analyzed weekly for both alpha and beta, suspended and dissolved radioactivity. The six-month averages of these measurements are given in tables 16 and 17. When these data are compared to previous monitoring data, including that taken prior to plant operation, there is no evidence that indicates that the liquid waste discharges have had any detectable effect on the level of radioactivity in the Ohio River.

Table 16. Radioactivity in Ohio River water, average concentrations in pCi/liter, January–June 1964

Location		Alpha	Beta
Upstream	Suspended solids	0.53	24.2
Downstream	Suspended solids	0.60	26.4
Upstream	Dissolved solids	0.61	40.1
Downstream	Dissolved solids	0.78	43.2

Table 17. Radioactivity in Ohio River water, average concentrations in pCi/liter, July–December 1964

Location		Alpha	Beta
Upstream	Suspended solids	0.13	13.1
Downstream	Suspended solids	0.26	25.1
Upstream	Dissolved solids	0.48	19.1
Downstream	Dissolved solids	0.56	26.8

Previous coverage in *Radiological Health Data:*

Period	*Issue*
January–June 1961	*April 1962*
July 1962–June 1963	*March 1964*
July–December 1963	*November 1964*

REPORTED NUCLEAR DETONATIONS, JULY 1965

During July 1965 the Atomic Energy Commission announced a nuclear test at the Nevada Test Site. The test was conducted underground on July 23, 1965, and was in the low-intermediate yield range (20 to 200 kilotons).